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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. XLIV.—*Further Study of the Solar Corona;* by Frank H. Bigelow.*

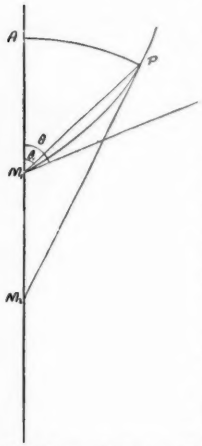
It was one of the proposed objects of the U. S. Eclipse Expedition to West Africa, in December, 1889, to make an effort to secure some photographs of the Solar Corona on a large scale, in order that certain measurements might be taken which would test fully the validity of the equation that I have assigned to the coronal curves. Inasmuch as we failed to obtain the desired pictures, in consequence of the clouds that prevailed during the minutes of totality, I have since my return to the United States made a series of measures upon photographs of the Coronas of 1878, July 29, 1889, Jan. 1, and 1889, Dec. 22, which have been generously placed at my disposal by the Superintendent of the Naval Observatory, and by the Directors of the Harvard College and the Lick Observatories respectively. I am also greatly indebted to Professor William Harkness for allowing me to use the Transit of Venus Measuring Engine, by Stackpole, and for all needful assistance. Six pictures have been measured, two La Junta negatives of July 26, 1878, taken by Professor Hall, two Creston negatives of July 26, 1878, by Professor Harkness, one positive of Jan. 1, 1889, by Professor W. H. Pickering at Willows, Cal., and one negative by Mr. Burnham at Cayenne, S. America, Dec. 22, 1889. As the computations are quite heavy the results of only one are presented with this paper.

* Read before the American Association at Indianapolis, August 22d, 1890.

The Equation of the Lines of Force.

The equation to be investigated may be derived as follows. Without raising the question of the physical constitution of masses of matter exhibiting the phenomena, we may understand by a polarized sphere, one in which magnetic or electrical potentials are to be referred to one general axis; or if not symmetrical, one in which the positive potential is distributed about one pole, and the negative potential about another pole, the poles themselves being the intersection of two nearly opposite axes with the spherical surface. The potentials at any points in space may be discussed as if the actual distribution of polarized matter were replaced (1) by a small magnet at the center of the sphere, the direction of the axes coinciding, or (2) by a surface distribution whose density varies from a maximum at the poles, with the cosine of the angle of the polar distance, to zero at the corresponding equatorial plane. The former is the result of bringing two equal masses of opposite signs very near each other at the center of the sphere, and the latter is the lamellar distribution. They each give the same equations for lines of force and equipotential surfaces respectively.

1.



Equation of lines of force and equipotential surfaces.

Let M_1, M_2 be any two electrified masses connected by an axis of reference; join any point P with M_1 and M_2 by straight lines, and with the axis A by any curve; across a cylindrical surface generated by AP, the flow of force from M_1 is N_1, and from M_2 is N_2, the constant total force being $N_1+N_2=N$. Let PM_1 be the curve formed by the locus of the point that will keep N the same while the position of P varies in a plane, and let the tangent to this curve at the point M_1 make the angle θ with the axis; N is called the order of a line of force. Considering a single mass, the flow of force corresponding to the circular zone whose angle at the summit is 2θ, is proportional to the cap whose height is $1-\cos\theta$.

$$\frac{N}{4\pi M}=\frac{1-\cos\theta}{2} \qquad N=2\pi M\,(1-\cos\theta).$$

Introducing this into the equation and limiting the case to equal masses of opposite signs, we obtain,

$$2\pi M_1(1-\cos\theta_1)+2\pi M_2(1-\cos\theta_2)=2\pi M(1-\cos\theta)=N;$$

whence, $$M_1\cos\theta_1+M_2\cos\theta_2=M_2+M_1\cos\theta.$$

and by our special case,

$$\cos\theta_1 - \cos\theta_2 = 1 - \cos\theta = \frac{N}{2\pi M}.$$

Now if these masses be brought infinitely near together, the θ_1 and θ_2 will differ by an infinitely small amount, h; we have,

$$\cos\theta_1 - \cos\theta_2 = 2\sin\frac{\theta_1+\theta_2}{2}\sin\frac{\theta_1-\theta_2}{2}.$$

$$= 2\sin\theta.\frac{h}{2} = \sin\theta.h.$$

$$= \sin\theta.\frac{2a\sin\theta}{r} = \frac{2a}{r}.\sin^2\theta,$$

where a is the distance apart of the particles, and r the mean distance of the point P from M_1M_2.

Hence, $$N = 2\pi(2Ma)\frac{\sin^2\theta}{r},$$

which is the equation of a line of force.

Term $2a.M$ is the moment of the system, and if we choose to deal only with the outside of a large sphere, it is equivalent to the layers of gliding on a polarized sphere, and these again to $u\sigma_0$, where u is the volume of the sphere $\frac{4}{3}\pi R^3$, and σ_0 of the surface density at the poles. Therefore,

$$N = \frac{8\pi}{3}.(\pi R^3\sigma_0)\frac{\sin^2\theta}{r}.$$

From this equation we may draw typical lines of force by assuming $\pi R^3\sigma_0$ equal to unity, and this is the best form for use until we have the means of determining the value of σ_0; thus we finally get,

$$N = \frac{8\pi}{3}.\frac{\sin^2\theta}{r}.$$

The Equation for Equipotential Surfaces.

The potential of a mass M_1 at a distance r_1 is, $V_1 = \frac{M_1}{r_1}$, and of a Mass M_2, at a distance r_2 is, $V_2 = \frac{M_2}{r_2}$. If these masses are equal and of opposite signs, at the point of intersection of r_1 and r_2,

$$V = V_1 + V_2 = \frac{M_1}{r_1} - \frac{M_2}{r_2} = M\left(\frac{1}{r_1} - \frac{1}{r_2}\right).$$

These surfaces are of an ovoidal form, with a single sheet, tending to merge into spheres in proportion as they approach the centers of action.

If the two points are located infinitely near together,

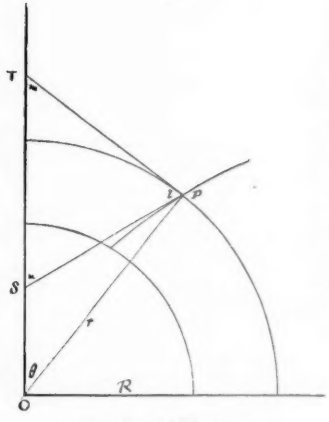
$$V = M.\frac{r_2 - r_1}{r_1 r_2} \text{ becomes } V = M.\frac{r_2 - r_1}{r^2} = M.\frac{2a.\cos\theta}{r^2}.$$

An equivalent of the moment of the system $2aM$ is as before, $2aM = \frac{4}{3}\pi R^3\sigma_o$, and the value of the potential at any point outside the sphere $(r.\theta)$ is $V = \frac{4}{3}\pi R^3\sigma_o.\frac{\cos\theta}{r_2}$.

Typical forms of the curves may be found by employing simply the expression, $V = \frac{\cos\theta}{r_2}$.

Gauss' Theorem of Polar intercepts.

2.



For Gauss' Theorem.

On the sphere whose radius is R, construct a line of force one of the points being $(r.\theta)$. Through $(r.\theta)$ draw a circle with radius r, a tangent to this circle making an angle m with the polar axis, and also a tangent to the line of force making the angle n with the axis. The triangle PTS will have the interior angles l, m, n, at corresponding vertices. Now,

$$PS.\cos l = OS.\sin\theta$$
$$PS.\sin l = TS.\cos\theta$$

Hence, $OS.\tan l = TS.\cot\theta = TS.\frac{\tan l}{2}$,

as can be proved by the discussion of the resolved forces. Therefore,

$$ST = 2OS, \text{ and } OT = 3OS.$$

The intercept from the center cut off by the force tangent is one-third the intercept cut off by the circle tangent.

This formula is also convenient for computing the inclination of the line of force to the normal as it leaves the surface of the sphere. If the lines are seen on the section of the meridian plane perpendicular to the line of vision, it applies directly, $\tan l = 2\cot\theta = 2\tan m$. If the angle actually seen is on any other meridian section, the projected value of the angle must be converted from its oblique to the perpendicular plane, by turning it through the angle a. Since l is the angle

of the line of force with the tangent, $90-l$ is its angle with the normal.

If l' is the apparent measured angle of inclination of a line with the radius extended, then $\tan l = \tan l' \sec a \sec \theta$.

In a preceding paper I applied this theorem to some photographs of coronal lines, finding a strong tendency to represent the intercept ratio in the four quadrants, and yet with such marked exceptions as might well lead to the interpretation that the agreement was fortuitous between the graphical representations of the mathematical formulæ and the natural phenomenon. It is now my object to carry out the comparison with considerable accuracy, paying regard to the distortions of the coronal lines as produced by the perspective effects. It may be possible sometime to include the corrections due to differential refraction, non-coincidence of the centers of the disks of the Sun and the Moon with the axis of vision, and such others as exist, but at present they must be omitted because the photographs used are too small to permit settings for measures within these limits of precision.

The Negative here discussed is

Marked No. 16, July 29, 1878, La Junta, Col., by Professor Asaph Hall. It was taken with a Dallmeyer's patent portrait and group lens, size No. 8 D; effective focal length 37·89 inches, clear aperture 6·0 inches; the plates were the dry washed emulsion; the size of the image of the Moon's disk is 0·362 inch, but the limb is not circular because of the Moon's motion in right ascension. The measurements were made by centering the image so that in revolving the table the edge of the disk remained tangent to the micrometer thread. Having selected the polar line of the corona by inspection, the readings of the N. and S. poles respectively were taken; then as many settings on individual rays as was practicable were made, the polar angle and the distance in micrometer revolutions read. The corresponding values of r and θ were made the basis of the computation.

North Polar Setting 251° 40′.

South Polar Setting 244° 30′.

The angle from the N. Pole through the east to the S. Pole is 172° 50′.

The North Pole lies 1° 10′ east of Sun's Axis.

The South Pole lies 6° 0′ east of Sun's Axis.

The reading for the North Pole is 7·55 divisions.

The reading for the South Pole is 7·45 divisions.

Correction for micrometer readings is for N. P. readings −1·00; for S. P. reading −0·90. The diameter of the disk is 13·10 divisions. The factor for reduction to the unit radius is 6·55.

A complete record of the readings is given in table No. 1.

TABLE I.

S. W. Quadrant.			S. E. Quadrant.		
Ray.	Radius.	Circle.	Ray.	Radius.	Circle.
	d			*d*	
1	7·55	254° 19′	1	7·55	250° 51′
	9·32	254 36		9·20	249 45
	10·50	255 0		10·70	249 20
2	7·50	256 1	2	7·55	250 33
	9·45	258 31		8·90	248 8
	10·90	260 12		10·20	244 0
3	7·55	258 30	3	7·58	242 33
	9·45	261 17		8·92	237 0
	10·87	262 56		10·30	233 10
4	7·55	260 40	4	7·56	237 18
	9·03	263 17		9·40	230 52
	10·60	265 38		11·25	223 8
5	7·55	264 41	5	7·57	233 26
	9·00	272 23		9·55	225 49
	10·12	276 5		10·80	220 36
6	7·60	276 52	6	7·56	230 48
	9·40	285 17		10·00	220 8
	10·52	290 41		11·80	213 50
7	----	--- --	7	7·58	220 26
	9·10	290 42		9·60	213 43
	10·28	299 8		11·18	208 12
8	----	--- --	8	7·66	217 2
	9 60	299 10		9·62	208 6
	11·10	307 38		11·16	201 23
	12·35	314 32		12·68	194 44
			9	7 57	210 0
				9·85	201 36
				11·85	192 37

N. E. Quadrant.			N. W. Quadrant.		
	d			*d*	
1	7·45	70° 50′	1	7·50	63° 15′
	9·00	73 38		9·10	62 30
	10·70	75 0		10·45	60 0
2	7·45	74 32	2	7·45	61 13
	9·30	77 52		9·20	59 0
	11·00	81 0		10·52	57 46
3	7·45	78 8	3	7·45	59 10
	9·33	81 36		9·20	55 29
	10·50	83 26		10·95	51 29
4	7·45	81 20	4	7·45	55 32
	9·33	87 51		9·44	50 25
	10·72	91 12		10·94	45 6
5	7·45	86 5	5	7·45	51 48
	9·20	90 57		9·30	44 16
	10·80	95 58		11·10	35 8
				12·24	31 4
6	7·45	93 47		13·52	26 56
	9·60	100 30	6	----	-- --
	10·90	105 1		9·20	26 56
7	7·45	103 1		11·56	13 16
	9·45	111 18		13·10	5 2
	10·91	115 48			
8	----	--- --			
	9·10	122 50			
	10·71	130 39			
	12·72	136 10			

TABLE II.

S. W. Quadrant.				S. E. Quadrant.			
Ray.	log r.	θ.	N.	Ray.	log r.	θ.	N.
1	0·00000	2° 39′	0·018	1	0·00000	0° 49′	0·002
	0·10388	2 56	0·017		0·09757	1 55	0·007
	0·16148	3 20	0·019		0·17053	2 20	0·009
2	9·99667	4 21	0·049	2	0·00066	1 7	0·003
	0·11062	6 51	0·092		0·08139	3 32	0·026
	0·17940	8 32	0·122		0·14755	7 40	0·106
3	0·00000	6 50	0·119	3	0·00208	9 7	0·209
	0·11062	8 37	0·146		0·08249	14 40	0·444
	0·17808	11 16	0·212		0·15224	18 30	0·594
4	0·00000	9 0	0·205	4	0·00066	14 22	0·515
	0·08848	11 37	0·277		0·10804	20 48	0 824
	0·16603	13 58	0·333		0·19448	28 32	1·229
5	0·00000	13 1	0·425	5	0·00133	18 14	0·817
	0·08685	20 43	0·858		0·11573	25 51	1·220
	0·14375	24 25	1·026		0·17053	31 4	1·506
6	0 00330	25 12	1·507	6	0·00066	20 42	1·209
	0·10804	33 37	2·001		0·13800	31 32	1·670
	0·16240	39 1	2·284		0·21718	37 50	1·912
7	----	----	----	7	0·00199	31 14	2·242
	0·09225	39 2	2·688		0 11826	37 57	2·413
	0·15131	47 28	3·211		0·19150	43 28	2·557
8	----	----	----	8	9·00723	34 38	2.655
	0·11826	47 30	3·469		0·11927	43 34	3·024
	0·18808	55 58	3·731		0·19065	50 17	3·195
	0·23876	62 52	3 829		0·25120	57 26	3·261

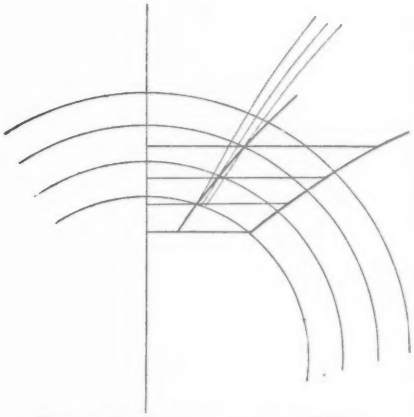
N. E. Quadrant.				N. W. Quadrant.			
1	0·00000	3 40	0·034	1	0·00330	11 15	0·199
	0 09225	0 52	0·001		0·09757	12 0	0 289
	0·17499	1 30	0·004		0·16376	14 30	0·360
2	0·00000	0 2	0·000	2	0·00000	13 17	0·442
	0·10804	3 22	0·023		0 10284	15 30	0·472
	0·18808	6 30	0·069		0·16694	16 44	0·473
3	0·00000	3 38	0·037	3	0·00000	15 20	0·589
	0·10959	7 6	0·099		0·10284	19 1	0·702
	0·16603	8 56	0·138		0·18593	23 1	0·835
4	0·00000	6 50	0·119	4	0·00000	18 58	0·885
	0·10959	13 21	0·346		0·11522	24 5	1·056
	0·17587	17 42	0·517		0·18549	29 24	1·317
5	0·00000	11 35	0·338	5	0·00000	22 42	1·248
	0·10284	16 27	0·530		0·10804	30 14	1·657
	0·17940	21 28	0·742		0·19236	39 22	2·164
					0·23837	43 26	2·287
6	0·00000	19 17	0·914		0·28825	47 34	2·347
	0·12328	26 00	1·212				
	0·13800	30 31	1·572	6	----	----	----
					0·10284	47 35	3·604
7	0·00000	28 31	1·909		0·21152	61 14	3·956
	0·11573	36 48	2·302		0·27012	69 28	3·940
	0·18419	41 18	2·388				
8	----	----	----				
	0·09757	48 20	3·736				
	0·17543	56 9	3 849				
	0·25638	61 40	3·597				

The first process was to substitute the resulting values of $r.\theta$ in the formula for the lines of force, $N=\frac{8\pi}{3}\cdot\frac{\sin^3\theta}{r}$. The computed values are collected in table No. II.

It is observed that the values of N derived from measures on the same ray are not equal. If all the circumstances are fully accounted for, they would be alike and the angle θ would show the same polar distance for the beginning of the line N. But it is seen that there is a marked progression in these values, which indicates that some systematic error adheres to the work. An inspection of the case suggests that the projection of the ray from its position in space upon the apparent plane of the disk must be taken fully into account, for it is not probable that any large number of the visible rays start from the body of the sun in the very plane of the disk. To such rays the formula should have applied. The problem is therefore to discover at what point of the sphere each ray originates, and to assign angular coördinates to the same.

The figure illustrates how a ray springing from the surface of the sun is seen projected so as to lie across a series of true N-lines represented as proceeding from the disk. What was computed in the last operation is in fact the particular N-line that passed through the point as measured in its projected situation. We must now discover a means of determining through what angle α the plane of the ray N must be rotated in order to be seen on the plane of the disk. Also we must carefully distinguish between the pole of the corona and the selected pole on the disk, for although these two poles lie in the same plane whose position angle with the sun's axis at the center of the disk has already been given, yet the angular distance of the coronal pole from the plane of the disk, being at this time unknown, has an immediate effect upon the angle α that is being sought. All the planes containing the rays intersect in the coronal axis, and if this was in the plane of the disk the rotation angle α would be the same for all measured points on the ray; otherwise α measured at the pole on the

3.



Ray projected across a series of N-lines.

disk will exhibit a progression of values as we pass along the ray. As each quadrant has been considered independently, no effort was made to generalize the angle α, but it is counted from the plane of the disk to the plane passing through the point on the ray, at the axis of intersection of the planes through the center of the sun.

$$N = \frac{8\pi}{3} \cdot \frac{\sin^3\theta}{r}.$$

Let $x_1 = r_1 \sin\theta_1$ and $y_1 = r_1 \cos\theta_1$, the accents indicating the first point that is measured on a ray.

$$r = \sqrt{x^2+y^2} \quad \sin^3\theta = \frac{x^3}{r^3} = \frac{x^3}{x^2+y^2}.$$

$$N = \frac{8\pi}{3} \cdot \frac{x^2}{(x^2+y^2)^{\frac{3}{2}}}.$$

As a first approximation, assume that the axis of the planes of rotation lies in the plane of the apparent disk; hence by rotating a ray from the edge of the disk to its actual position, the values of y are unchanged, while those of x are reduced. The radius of revolution is $x_1 = r_1 \sin\theta_1$, therefore $x = x_1 \sec\alpha$.

Substituting, $$N = \frac{8\pi}{3} \cdot \frac{r_1^2 \sin^2\theta_1 \sec^2\alpha}{(r_1^2 \sin^2\theta_1 \sec^2\alpha + r_1^2 \cos^2\theta_1)^{\frac{3}{2}}}.$$

Since the points are on the same ray, we take

$$\frac{r_1^2 \sin^2\theta_1}{(r_1^2 \sin^2\theta_1 \sec^2\alpha + r_1^2 \cos^2\theta)^{\frac{3}{2}}} = \frac{r_2^2 \sin^2\theta_2}{(r_2^2 \sin^2\theta_2 \sec^2\alpha + r_2^2 \cos^2\theta_2)^{\frac{3}{2}}}.$$

$$\frac{(x_2^2 \sec^2\alpha + y_2^2)^{\frac{3}{2}}}{(x_1^2 \sec^2\alpha + y_1^2)^{\frac{3}{2}}} = \frac{x_2^2}{x_1^2}.$$

$$\sec^2\alpha = \frac{x_2^{\frac{4}{3}} y_1^2 - y_2^2 x_1^{\frac{4}{3}}}{x_1^{\frac{4}{3}} x_2^2 - x_2^{\frac{4}{3}} x_1^2}.$$

The application of this formula gives the values of α corresponding properly to the mid-point between the two points from which it was derived. They also have a progressive value, indicating that the pole of the corona is not on the plane of the disk. It will not be far wrong to assume that value of α which is nearer the first α than the second, as would be seen by inspection from the points on a sphere.

Now substituting these values of α in

$$N = \frac{8\pi}{3} \cdot \frac{x^2 \sec^2\alpha}{(x^2 \sec^2\alpha + y^2)^{\frac{3}{2}}},$$

we find that the ranging nature of the NS has ceased, and that there remain only such irregularities as are occasioned by the inaccuracy of the measurements themselves.

TABLE III.

S. W. Quadrant.					S. E. Quadrant.				
Ray.	a.	Adopted a.	θ.	Mean θ.	Ray.	a.	Adopted a.	θ.	Mean θ.
1	87° 16′	87°	35° 0′		1	88° 34′	88° 50′	31° 41′	
	87 48		31 41			87 18		33 25	
			30 21	32° 41′				29 28	31° 31′
2	84 16	84	29 22		2	88 27	88 40	30 28	
	82 0		31 23			85 49		32 34	
			30 44	30 30				(22 23)	31 31
3	82 25	82	33 59		3	79 26	79	34 25	
	79 36		32 26			71 53		34 59	
			30 50	32 25				31 48	33 44
4	77 40	78	30 17		4	71 21	71	33 45	
	72 50		31 25			65 10		34 1	
			30 14	30 38				31 38	33 8
5	74 55	75	33 51		5	65 43	66	34 1	
	64 15		35 51			60 40		34 19	
			33 20	34 21				33 25	33 55
6	57 4	59	36 33		6	62 8	62	34 52	
	51 1		36 35			48 6		34 54	
			35 41	36 16				32 38	34 8
7	----	--	----		7	41 54	42	35 8	
	48 51	48	38 59			34 33		35 13	
			38 57	38 58				35 11	35 11
8	33 15	33	41 6		8	40 20	40	39 7	
	23 12		41 7			31 39		39 11	
			40 30	40 54		28 16		38 39	
								37 26	38 18

N. E. Quadrant.					N. W. Quadrant.				
Ray.	a.	Adopted a.	θ.	Mean θ.	Ray.	a.	Adopted a.	θ.	Mean θ.
1	----	--	----	----	1	----	----	33° 5′	
	89° 22′	89°	30° 48′			74° 14′	75°	30 17	
			28 35	29° 42′				30 2	31° 8′
2	89 48	88 50′	----		2	58 50	65	28 2	
	88 53		28 32	28 32		16 3		27 41	
			(19 27)					26 11	27 18
3	85 21	85	28 43		3	73 12	73	36 30	
	81 45		32 55			64 40		34 5	
			30 59	30 52				32 5	34 40
4	81 20	81	31 8		4	67 55	68	34 52	
	74 38		33 39			45 6		33 30	
			30 32	31 45				32 26	33 36
5	74 50	75	32 41		5	59 17	59	34 24	
	69 57		33 17			54 58		35 0	
			31 32	32 50		39 30		34 23	
						28 10		33 5	
6	61 37	64	33 25					31 29	33 37
	68 32		33 18						
			34 34	33 46	6	30 16	30	41 55	
								41 58	
7	48 59	49	36 0					40 49	41 34
	30 58		36 23						
			35 16	35 53					
8	23 20	24	42 25						
			42 23						
			40 16	41 41					

Take the typical formula for N and compute $\sin^2\theta = \frac{3}{8\pi}.\mathrm{N}$. The angle θ derived from this is the distance from the coronal pole at which the observed rays have sprung up from the surface of the sun. The values may be slightly in error by the small inaccuracy of the chosen a, but the changed projection resulting from this imperfection is not great.

This table shows that the coronal rays have their bases in a zone about 34 degrees from the coronal pole, the belt being about ten degrees in width, but its maximum density at the parallel of 34 degrees. The conclusion is drawn that there are no visible rays in the neighborhood of the poles, and hence the appearance of the corona is similar to that of the terrestrial aurora.

Position of the Coronal Poles.

We find the location of the north and south poles of the corona in the following way.

Let $r_1\,\theta_1$ represent the measured coördinates of each point, with the numerical suffix.

α_1 = angle at pole of disk to the point on the ray.

p_1 = angular distance from pole of disk to point.

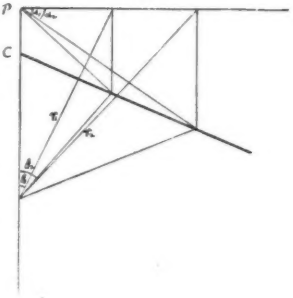
θ' = angular distance from coronal pole to point.

r' = radius of spherical surface through point.

B = angle at coronal pole from pole of disk to point.

c = angular distance of coronal pole from pole of disk.

4.



P = projection of coronal pole c on a plane through the poles of the ecliptic.

Then $x_1 = r_1 \sin\theta_1$.

$y_1 = r_1 \cos\theta_1$.

$z_1 = x_1 \tan\alpha_1$. $\mathrm{D}_1 = x_1 \sec\alpha_1$.

$$\tan p_1 = \frac{\mathrm{D}_1}{y_1} = \tan\theta_1 \sec\alpha_1.$$

$$r^2 = {x_1}^2 \sec^2\alpha_1 + {y_1}^2.$$

$\mathrm{N} = \frac{8\pi}{3}.\frac{\sin^2\theta_0}{r}$, where $r = 1$ for typical N, and θ_0 is the mean angle as computed.

$$\sin^2\theta' = \frac{3r}{8\pi}.\mathrm{N}.$$

In the Spherical Triangle ABC we have given, $a = \theta'$, $b = p_1$, $\mathrm{A} = 90^\circ - \alpha_1$.

Hence, $\sin\mathrm{B} = \sin p_1 \cos\alpha_1 \operatorname{cosec}\theta'$.

$$\tan\tfrac{1}{2}c = \frac{\cos\frac{1}{2}(\mathrm{A}+\mathrm{B})}{\cos\frac{1}{2}(\mathrm{A}-\mathrm{B})}.\tan\tfrac{1}{2}(p_1+\theta').$$

TABLE IV.

S. W. Quadrant.

Ray.	log r'.	θ'.	p.	A.	B.	c.	Mean c.
1	0·12501	38° 35′	41° 29′	3° 0′	176° 49′	2° 51′ 18″	
2	0·08771	34 9	36 3	6 0	173 42	1 58 4	
3	0·11735	37 51	40 44	8 0	171 29	2 56 34	
4	0·09399	34 36	37 18	12 0	167 11	2 45 20	
5	0·11606	40 10	41 46	15 0	164 30	1 12 16	
6	0·09166	41 6	42 25	31 0	148 6	1 8 56	
7	0·17873	50 45	50 28	42 0	138 13	−0 23 42	
8	0·16308	52 11	52 27	57 0	122 41	0 30 34	1° 44′ 58″
				S. E. Quadrant.			
1	0·08655	37 17	35 0	1 10	178 47	1 37 56	
2	0·08100	35 6	39 57	1 20	165 8	0 0 0	
3	0·11272	39 13	40 40	11 0	168 48	0 51 38	
4	0·09148	37 24	38 11	19 0	160 39	0 49 34	
5	0·08849	38 10	39 0	24 0	155 32	0 54 26	
6	0·08014	37 59	38 50	28 0	151 25	0 58 48	
7	0·04482	37 21	39 13	48 0	129 15	2 51 32	
8	0·05173	41 8	42 2	50 0	128 47	1 23 50	1 10 58

Mean value of c for the south pole, 1° 27′ 58″.

N. E. Quadrant.

Ray.	log r'.	θ'.	p.	A.	B.	c.	Mean c.
1	0·21388	39° 20′	40° 55′	1° 0′	178° 58′	1° 35′ 0″	
2	0·09159	34 45	36 4	5 0	174 50	1 20 14	
3	0·09717	36 3	37 27	9 0	170 42	1 24 30	
4	0·09678	37 19	38 23	15 0	164 38	1 5 16	
5	0·08194	38 41	38 36	26 0	154 3	−0 5 28	
6	0·05725	38 46	39 38	41 0	138 4	1 8 58	
7	0·12036	49 48	50 53	66 0	111 53	2 46 18	1° 9′ 21°
				N. W. Quadrant.			
1	0·09564	35 15	37 33	15 0	164 8	2 24 2	
2	0·05720	29 20	29 11	25 0	155 7	−0 6 38	
3	0·12128	40 52	43 10	17 0	162 12	2 24 30	
4	0·10837	38 49	42 32	22 0	156 10	4 2 34	
5	0·07499	37 8	39 5	31 0	147 28	2 17 1	
6	0·13909	51 9	51 39	60 0	119 18	1 0 32	2 0 20

Mean value of c for the north pole, 1° 34′ 51″.

If θ' is smaller than p, c is positive, and the coronal pole is on the earth side of the plane of the disk.

This table is computed by taking the first point measured on each ray, and selecting the values of r_1, θ_1 from Table II, and a, θ_0 from Table III. As shown by the formula, r' θ' is the computed point whose coördinates of projection were meas-

ured; p is the angular distance from the pole on the disk; A and B the interior angles of the triangle at the respective poles, and c the required angular distance of the coronal pole from the disk plane.

Now investigate the heliographic latitude over which these coronal streamers appear to terminate as definite lines. By many computations it is found that the r for the extreme points measured is equivalent to the $\log r' = 0{\cdot}39800$, of lines which leave the sun at polar distance $\theta' = 34°$.

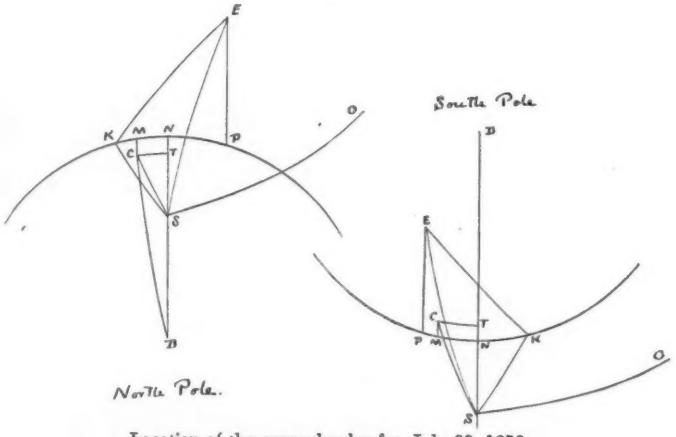
$$N = \frac{8\pi}{3} \cdot \frac{\sin^2\theta}{r}, \text{ where } r = 1 \text{ at the surface; hence } N = 2{\cdot}620.$$

$$\text{Then, } \sin^2\theta = \frac{N \cdot 3r'}{8\pi}; \text{ and } \theta = 62° \; 10'.$$

The corresponding equatorial distance is $90° - 62° \; 10' = 27° \; 50'$, which is in the midst of the zone of the sun spots at the minimum of the period.

The heliographic latitude and longitude of the north and the south coronal poles, as seen on July 29, 1878, are obtained as follows.

5



Location of the coronal poles for July 29, 1878.

K Poles of the ecliptic.
S Poles of the sun's axis.
E Poles of the plane of the equator.
C Poles of the corona.
D The center of the disk.
KP The plane through the poles of the ecliptic perpendicular to the radius vector to the earth.
M The projection of poles of the corona on the disk.
N " " " sun " "
P " " " equator " "
O The direction of the ascending node at 74° longitude.

The North Pole.

KN Position angle KDS = + 4° 27′·6 counted from N to W.
KP " EDK = −14° 22′·1 " N " E.
PN " EDS = − 9° 54′·5 " N " E.
NM Position angle of coronal pole = −1° 6′ counted from N to E.
MC Angular distance of coronal pole from plane of disk, on the side towards the earth = 1° 34′·8.
PM Position angle of coronal pole = −11° 0′·5 counted N to E.
KS The inclination of the sun's equator = 7° 15′.
NKS = (270° + ☉) − (270° + 74°) = 126° 10′·97 − 74° = 52° 10′·9.
tan NK = cos NKS tan KS = 8·89212. NK = 4° 27′·6.
sin SN = sin NKS sin KS = 8·99866. SN = 5° 41′·6.
ST = SN − CM = 4° 6′·8. CT = MN cos CM = 1° 5′·97.
cos CS = cos CT cos ST = 9·99880. CS = 4° 15′·4.
cot CST = sin ST cot CT = 0·57257. CST = 14° 58′·8.
NKS = 52° 10′·9. NSK = 38° 2′·6. NSC = 14° 58′·8.
CSK = NSK − NSC = 23° 3′·8. OSK = 90°.
OSC = OSK − CSK = 66° 56′·2. Heliographic longitude.
90 − SC = 85° 44′·6. " latitude.
Coördinates of the north coronal pole:

Long.	66° 56′·2
Lat.	+85° 44′·6

The South Pole.

KN = KDS = − 4° 27′·6 counted E from S.
KP = EDK = +14° 22′·1 " W " S.
PN = EDS = + 9° 54′·5 " W " S.
PM = EDC = 3° 54′·5 " W " S.
PKS = 52° 10′·9.
KS = 7° 15′.
SN = 5° 41′·6. MN = 6° 0′.
KN = 4° 27′·6. MC = 1° 28′·0.
ST = 7° 9′·7.
cos SC = cos ST cos CT = 9·99420. CT = 5° 59′·88.
SC = 9° 20′·5.
cot CST = sin ST cot CT = 0·07400.
CST = 40° 8′·5.
SKN = 52° 10′·9.
NSK = 38° 2′·6.
CSN = 40° 8′·5.
CSK = 78° 11′·1. OSK = 90.
OSC = 168° 11′·1. Heliographic longitude.
90 − SC = 80° 39′·5. " latitude.
Coördinates of the south coronal pole:

Long.	168° 11′·1	Difference of longitude.
Lat.	− 80° 39′·5	101° 14′·9

It is interesting to compare these coördinates of the polarization of the sun with the similar coördinates of the magnetism of the earth, as given by Erman and Petersen for 1829, from Gauss' Theory.

North Pole,	Long.	266° 3′·8
	Lat.	73° 21′·
South Pole,	Lon.	150° 44′·9
	Lat.	— 72° 40′·4

Difference of Longitude, 115° 18′·9

This fact of general agreement of the difference of longitude may be purely accidental, or it may point to some fundamental law of polarized rotating spheres.

This analysis of the solar corona suggests certain conclusions.

1. The force seems to be repulsive, the law of its action being expressed by a transcendental equation of the second degree. This agent is sufficient for the transportation of finely subdivided matter, and harmonizes with the lack of density of the sun's atmosphere, as indicated by its failure to influence the motion of comets passing within its limits.

2. The individual streamers are grouped in a zone about ten degrees wide, whose maximum density is at 34 degrees from the coronal poles. The number of such rays is not great, but their actual dimensions are enormous. The average linear *visible* extension is about one solar radius, and regarding the residual propulsion and curve of the trajectory their extremities are located normally above the sun spot belts. At this place the incandescence of the material particles apparently ceases, and if condensation sets in, there would exist the conditions required for the precipitation of cool masses, whose fall upon the surface of the sun is generally supposed to produce the spots. It is at this zone of maximum for the coronal rays that the deficiency of the prominences has been observed, and there may well be a physical connection between these two classes of phenomena. The re-entering form of the curves is also consistent with the existence of atmospheric currents flowing from the polar regions towards the equator, and a study of the angles of inclination of the prominences relatively to normals may develope some evidence on this point. The condensed bodies of light, seen on two axes at 40 degrees from the poles, are doubtless due to the perspective effects of the maximum zone as it passes around the sides of the sun; and the structureless equatorial wing is no doubt a floating mass of matter, cooling in the process of preparation for precipitation. This return of the ejected matter to the sun is considered necessary to account for the relation of the total flow of

energy outwards and the rate of change in its volumetric dimensions, as derived from theory.

3. The location of the coronal poles at successive eclipses will afford a means of determining the period of the rotation of the sun on its axis, in consequence of the large number of revolutions occurring between such epochs. It would be necessary to assume that the axis of polarization of the sphere remains the same, as is probably the case.

4. The accelerated angular velocity of the equatorial belts as compared with the polar regions, would result from the descent of cool matter from high altitudes above the surface of the sun, each particle being considered as a satellite approaching its center of gravity. The motion of the spot belts in latitude synchronously with the display of energy as recorded by the maxima and minima, may be due to a corresponding motion of the maximum zone towards and from the poles, with the accompanying elevation of the ends of the coronal stream lines; or to changes in the relative energies of propulsion, as a function of the time. It is possible that a picture of the corona may be sometime taken which will show these streamers distributed in two parallel belts a few degrees apart. It is a most interesting question in physics as to the reason of the location of this coronal zone at the computed distance from the poles, since it suggests also a problem similar to that of the terrestrial auroras. At this place the linear distance across the greatest number of equipotential surfaces, is apparently the shortest, hence it may be the path of least resistance. There should also be a connection between the distribution of the actinic light of the corona and the equipotential surfaces, and it is not unlikely that the light is simply proportional to the potential.

This discussion suggests the importance of securing photographs of the corona sufficiently large to admit of accurate measurements; the necessity of studying the relation between the position of the streamers and the spots at the moment of the eclipse; and the possibility of deriving the period of the sun's axial rotation from the coronas of successive eclipses.

Art. XLV.—*Superimposition of the Drainage in Central Texas;* by Ralph S. Tarr.

In the number of this Journal for last May the writer described the general history of the drainage system of Central Texas as far as it could be read with our present knowledge of the region. In that paper it was shown that the present drainage is superimposed, having originated upon the Cretaceous strata in Tertiary times and, after removing this covering from the buried Paleozoic rocks, finding itself superimposed upon these hard rocks. There is abundant proof of this; for the central Paleozoic region is only partially uncovered and the denudation of the Cretaceous is still in progress. One of the chief effects of the superimposition is that the Colorado river, one of the great arteries of eastern Texas, flows, in its middle course, for many miles over hard Silurian marble containing great quantities of flint. This barrier, accidentally discovered in cutting through the Cretaceous, has retarded the river in its down cutting.

Since writing the former paper two points connected with the drainage of Central Texas, which then puzzled me, have become clear; and as they are interesting confirmations of the superimposition theory for the origin of the present drainage of the region I give them below.

A superimposed river, having selected its course with reference to a structure now no longer present, naturally finds itself flowing without reference to the nature of the newly discovered beds. Thus it is that the Colorado in central Texas is now busy with a barrier of hard Silurian rock, and thus it is that this river flows with a general course at right angles to the strike of the Carboniferous rocks and in an opposite direction to the dip.

Not only the Colorado itself, but all its tributaries flow without especial reference to structural weakness; but the smaller branches take advantage of the structural peculiarities, showing, in many cases, that they are more recent in origin than the time of removal of the Cretaceous. Moreover, some of the medium-sized streams, which in their upper and middle course flow, perhaps on Cretaceous, quite regardless of Carboniferous structure, have nearer their mouth partly readjusted themselves to the new conditions. The number of strike valleys in the lower course of such streams is quite astonishing since it shows to how great an extent drainage is dependent upon structure and how readily, even under great disadvantages, streams will make use of such weaknesses. In the Carboniferous this is

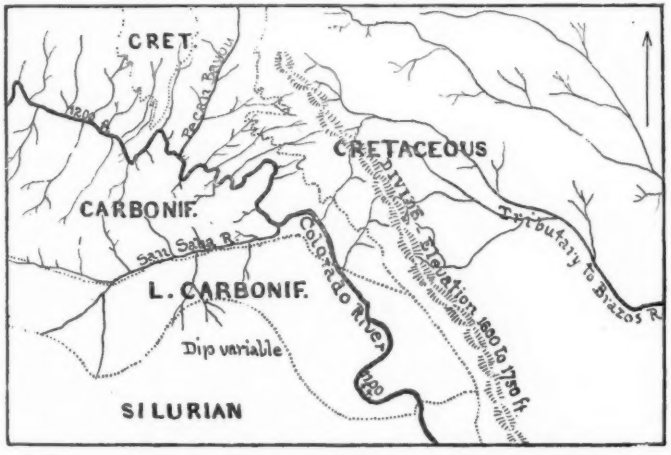
particularly noticeable in valleys carved in soft clays and shale. For instance, the Waldrip Division of soft coal-bearing beds, for a distance of more than 30 miles, is marked by a topographic depression. A single stream does not follow this line of weakness continually as would very likely have been the case had the Carboniferous formed an original drainage-surface, but small streams have their head-waters here and larger creeks flow in it for some distance before leaving it to cross the hard underlying limestone.

Everywhere may be seen signs of attempts at rejuvenation, but it was not until lately that I was able to see that the Colorado itself shares this peculiarity. This river flows with a very serpentine course through the Carboniferous, having a length along the boundary of San Saba county of 50 miles, while at the end it is only 30 miles from the first point. In one place it makes a bend six miles long where a cut off would reduce the distance to two miles. Several possible reasons suggest themselves in explanation of this phenomenon which is quite remarkable in a river with a fall of from two to three feet per mile. Since the Colorado is a superimposed river flowing in its present course chiefly by accident, it is possible that before the Quaternary uplift the river may have been sufficiently old, in this part of its valley, to have the serpentine course common to such rivers. Thus the present form of valley may be inherited from that time. Another possible cause is that the slow removal of the Silurian by retarding the down-cutting in this part of the river-channel has induced a temporary old-age condition. That this is the case to a certain degree is abundantly proved by the extensive flood-plains of the Colorado and its side streams; but whether this is a sufficient cause to account for the phenomenon at present under consideration is doubtful. It may be that both these causes have had some effect, but the chief cause is quite different and is to be found in the futile attempt of the Colorado to adjust itself to the new conditions which it has found in its enforced path, probably aided somewhat by the Silurian barrier which has prevented rapid down-cutting.

The evidence of this attempt at readjustment is that all the main bends in the river have one, and generally both, of the long sides of the loop parallel to the strike of the Carboniferous. This is the case in eleven distinct instances, and in one case the river flows northeast for four miles before turning and cutting across the strike to resume its natural course. Above Elliot Creek in Mills county there is a stratum of coarse, thick-bedded sandstone, which has deflected the Colorado river southwest along the strike for a distance of three and one-half miles

before it cuts across it; and then the river flows northeast for a mile before resuming its natural direction southeastward.

Another hitherto unexplained phenomenon in connection with the drainage of Central Texas is that the divide between the Brazos and the Colorado rivers is close to the latter, being in places only six miles distant, while it is fully seventy-five miles from the former. All along the entire course the Colorado has almost no drainage area on the east side. The reason for this, so long a puzzle to me, now seems plain—it is the result of accidents, brought about by superposition. The accompanying diagram illustrates this peculiarity of drainage.



It is probable that both the Brazos and the Colorado originated under practically the same conditions, that is, upon the new Cretaceous land elevated above the sea during the great Tertiary mountain uplift. Their course was plainly chosen with reference to conditions appearing on the surface then existing without regard to what lay below. After cutting through the soft, nearly horizontal Cretaceous rocks, the Colorado came upon the buried Paleozoic and encountered not only the Carboniferous for a considerable distance, but also the much harder Silurian with which it has long been struggling. The Brazos, on the other hand, by the accidental choice of a more easterly course avoided these difficulties. To be sure this river in its middle and upper course is superimposed upon the Carboniferous rocks, but the removal of these is a very simple task compared to that the Colorado had imposed upon it. The consequence of this difference between the two rivers is that while the Colorado in Mills county flows at an elevation

of 1,200 feet above the sea-level, the Brazos in the same latitude has cut down to within 600 feet of the sea-level in its soft bed.

This fact has given the Brazos a great advantage over its competitor, the Colorado, for drainage territory; and this, in the battle for conquest of headwater drainage area, has enabled the Brazos to push the divide close up to the Colorado in territory, which, under more favorable circumstances, should belong to the latter stream. The side streams of the Brazos having a much lower plane to which it was possible to base level the drainage area than those of the Colorado had were much more powerful agents of erosion; and the result is that a tributary to the Colorado from the east is rarely 10 miles long, while Brazos tributaries, heading in the same divide, flow fully 75 miles before emptying into their mother stream.

ART. XLVI.—*A description of the "Bernardston Series" of Metamorphic Upper Devonian Rocks;* by BEN K. EMERSON.

[Continued from p. 275.]

The position and extension of the basal quartzite was the first clue to the complex stratigraphical arrangement of the series in its eastward continuation. Beginning at the point already described, east of the road to East Mountain (back of "Mrs. Haley's" on the map), with a strike due east, it has bent round to N. 65° E. before it goes under the massive drumlin which lies east of the river, and on its emergence, it is abundantly exposed, with the same strike, along the southern of the two northwest roads mentioned above, especially south of A. G. Chapin's house. Taking the direction of this road across the valley of Dry brook, it can be followed readily, with the same strike and low S.E. dip and physically unchanged, through the chestnut woods N.W. of the end of Purple's blind road, crossing the first north and south road in Northfield, where a loop of the brook crosses the road; and gradually bearing round to the north, it crosses the State line with a strike N. 10° W.

(*b*) *The quartzite conglomerate.*—Back of Mrs. Haley's, on the Fall River road, and just east of the Williams farm, across the valley, ledges of the rock appear, and it outcrops abundantly along the second road running east from the Fall River road (A. G. Chapin's) to its end. Where the road begins it is an obscurely bedded conglomerate of quartz pebbles, in a dark paste containing much slaty material. The conglomerate here toward its base is exactly like the same rock west of the lime-

stone on the Williams farm, and I have no doubt that they were formerly connected across the valley. Higher up, the rock is a pudding stone with rounded quartz pebbles up to 100^{mm} in length, but mostly 20–30^{mm} long; the abundant quartz sand paste, which wraps round them, cleaves into thick layers coated with muscovite scales and iron rust, so exactly like the upper quartzite of the Williams farm, especially the conglomerate layer, that it is difficult to avoid the conclusion that they are also parts of a single stratum. Calculated upon its average dip of 20° the thickness of the bed is 123 meters, which is only a rough approximation.

In the field south of A. G. Chapin's house is an interesting outcrop. The rock is here jointed with almost mathematical accuracy, into acute rhombs, the joint-planes passing through the quartz pebbles; and the latter are finely compressed, and indented one by another. The rock here carries garnets 5^{mm} across. The rock is unchanged across Dry Brook for a long distance to the northeast, when it crosses the last road; but once over the range (J. M. Picket) at a point where the brook makes a loop across the road, the pebbles are flattened out into thin disks, resembling the small lenses of quartz common in crystalline rocks, making it almost doubtful if they may not be of secondary origin—a doubt which does not extend to the range described above. In the woods, southwest of this point, the rock in some beds is in appearance a fine-grained biotite-gneiss, with large garnets surrounded by a broad annular colorless space, in which the biotite is wanting; and in following the band farther north, the pebbles grow smaller, and where it crosses the State line it is below a thin-bedded biotitic quartzite, above a muscovitic quartzite; and in some layers the muscovite becomes abundant and wraps around pencils of quartz, so that the rock obtains a rude columnar or ligniform structure. It has here an apparent thickness of 107 meters.

At the point already mentioned on the grist mill road (J. M. Pickett) where the brook makes a short loop across the road, at the south bridge is a fine section in a high bluff, west from the bridge. The conglomerate strikes N. 45° E. and graduates downward through fifty feet of quartzite into fine micaceous quartzite and this into flat argillite with minute transverse biotites. The whole is well exposed and plainly conformable. Its dip increases from 22° at the south end to 45° at the north end, where the upper portion of the bed has this high dip, while the lower portion runs up on the argillite with the low dip of 20°. It thus folds around and dips away from a great promontory of the argillite; and it is blackened in many places by a remnant of the argillitic material.

Just after crossing the State line into South Vernon it bends sharply to the southwest, recrosses the State line and, at the point where the grist-mill road (J. M. Pickett) crosses the town-line, bends again northwest and swings in a great curve north across Vernon. All this is well exposed just north of the last house before crossing the line (M. Merrills), and the argillite where it is nipped by the sharply bending quartzite is greatly crushed and filled with quartz combs. This boundary crosses the next road north—the old Bernardston-Vernon road —at a small abandoned house (two houses below the school house) where the brook comes nearest the road. Just behind this house in the side of the brook is exposed a most interesting junction of the conglomerate upon the argillite. Commencing at a ruined dam perhaps 15 rods from the house we find typical argillite which changes through a few feet of spangled schist into thin fissile black muscovitic quartzite with some thicker highly crystalline layers, and this graduates into a highly muscovitic very vitreous quartzite, which is at one place a conglomerate of rounded quartz pebbles 2 to 4 in. long. This is where the water falls over a reef 3 to 4 feet high; it is 2 rods below a wooden bridge. Immediately below is a bed of heavy hornblende rock, massive, in places showing a reticulated structure: masses of this rock built into the piers of a wrecked bridge just behind the house show pebbles, and contain also much green mica, often quite coarse and resembling the more gneissoid rock found out over the South Vernon plain to the river and classed by Professor Hitchcock as Bethlehem gneiss. The series strikes N. 55° W. and dips 45° E. The outcrop is continuous and shows a gradual passage through a spangled argillite and fine-grained quartzite into conglomerate, often coarsely garnetiferous, the change being effected within 50 feet and showing no trace of unconformity. Many masses of a thin fissile pyritous magnetite occur here, but the bed could not be found in place.

East of the boundary line just described, across Vernon to the river, the whole area is underlaid by the basal quartzite except where the West Northfield schist series extends across the State line, west of the village of South Vernon; and across the brook it rises in the hill back of S. Titus's, where the road to the lily pond branches from the Brattleboro road. It dips for the most part to the east except east of the lily pond, where a minor fold of considerable size occurs, caused by the sharp bend of the quartzite on the State line, and here the beds dip south. Followed eastward it becomes more and more feldspathic and the muscovite is largely replaced by biotite, forming a completely gneissoid rock. It is here not distinguish-

able from the feldspathic quartzite occurring east of the West Northfield series and described below.

The Vernon limestone. — On the Lily Pond road above mentioned and just east of E. G. Scott's house occurs a band of limestone. It is a coarse granular limestone, highly crystalline, of light color, containing some garnet, hornblende and green mica. It contains what seem to be distinct traces of corals and crinoids and in everyway closely resembles the Bernardston bed with which I identify it without hesitation. Especially do the weathered surfaces show a peculiar conglomerate-like structure common at Bernardston. Large rounded fragments of a fine grained white limestone are cemented by a coarser and more highly crystalline limestone, the latter in large amount, as if the rock had been brecciated by pressure and then the fragments rounded by percolating waters and re-cemented. This bed is exposed about 30 rods and may have a thickness of as many feet, but its boundaries are not well exposed. Toward the west it graduates on the strike into a calcareous hornblende schist, and above that, to the south, through an actinolitic quartzite into a quartzite abounding in large garnets and blotches of a greenish mica, while below it is succeeded by very coarse hornblende schist in large force. The whole series is enclosed in the gneissoid quartzite.

Description of the range from Bernardston to South Vernon.—Directly opposite the Williams farm and 200 rods distant, on the east side of Fall River, begins a range of low hills, which runs northeast between the two towns named above. This range of hills is backed on the northwest by a much higher range of argillite hills—Bald Mountain, Pond Mountain—and bounded on the southeast by the high terrace sands through which one large area and many smaller islands, of the rocks of the Bernardston series, emerge. I have called this the West Northfield range, from the town in which it for the most part lies. The road running along the east side of Fall River skirts the range at its western end, and the main road from Bernardston to South Vernon borders it on the south and east, while the roads which branch from the latter and cross the range are named from some resident upon each, as given in Beers' atlas, and as marked on the map on page 264.

The mapping of this area was difficult both because the rocks are thrown into great confusion, many beds being in places echeloned, so that the local strike regularly disagreed with the general run of the bands, and because of the presence of several large drumlins which effectually conceal the underlying rock. The intervening areas are, however, so entirely free from drift, up to the very foot of these hills, that, were it not heavily wooded, the region would furnish abundant outcrops, and, as

it is, the fragments on the surface can be safely used to determine the rock below. The series wraps round the argillite, and uniformly dips away from it, generally at low angles, at first south, and then for a long distance southeast; then it swings sharply round, crossing the State line with dips a little north of east, making thus a great bend to the westward as it crosses the town of Vernon. I have not been able to prove the existence of folds or overturns, and the present position of the beds seems to be best explained as the result of very extensive faulting.

(*a.*) *The Argillite.*—I have assigned to the argillite the broad area marked "Coos" upon Professor Hitchcock's map, to which he also assigns the slates of the Bernardston series, because I have found that the boundary between it and the argillite to the west, as given upon that map, has no justification in any physical change in the character of the rock where it is drawn, and the argillite can be traced unchanged up to and dipping beneath the quartzite next described. It is true that minute scattered garnets and very small staurolites are found sparingly in the rock in some places in this area, and these seem to have been relied upon by Professor Hitchcock in making the assignment of the rocks to the Coos; but the same garnets can be found at times in the undoubted argillite in West Mountain, and these, and the same minute staurolites, occur in the center of the Whately argillite, and both the minerals are very different from their representatives in the Coos group. Both in macroscopical and microscopical structure, the rock remains quite constant up to the quartzite, and in its finer grain, its darker color, its excessive contortions, and its abundant and large quartz veins, it is well distinguished from the slates of the higher series.

(*c.*) *The mica schist and hornblende beds.*—Resting on the basal quartzite, and dipping from it with low angle to the south, southeast and east successively, as it folds around conformably with it, is a broad area of mica schist, with several bands—probably five—of hornblende rock, and a central band of gneissoid quartzite. From the unequal rigidity of these rocks, they are thrown into great confusion, and from the similarity of the rock in the separate bands, the tracing of them is very difficult, and as they are placed upon the map, a greater regularity appears than exists in the field, many bands being made up of the slightly shifted portions of what was originally one, and many minor faults being of necessity neglected.

In general the schist is, below, finer grained, more slaty, with small development of the transverse mica, without stauro-

lite, and with quite small garnets, becoming, above, coarser, of rougher surface, and knotted with large staurolites.

At the south end, nearest the Williams farm, the basal quartzite dips beneath a very fine-grained flat fissile mica slate, which dips 20° in the direction S. 10° E., its surface sparsely pimpled with small garnets, and without other accessories and closely like the underlying schist of the Williams farm section.

The lowest bed of hornblende rock, here thin and poorly exposed, is followed by a second band of mica slate exactly like the first, which passes with the same dip and strike beneath a massive, dark gray to greenish-black hornblende rock, greatly jointed, and this is exposed in a broad area nearly down to the main road running east from Bernardston, and extending east to the house of S. J. Green, 100 rods west of the locality mentioned by Professor Dana.* It contains a central band of dark limestone at times 30^{cm} thick. The hornblende rock is capped by a thin layer, never more than a meter thick, of a shining, white arenaceous mica schist, with scattered scales of biotite, and a similar layer was found to cap a similar hornblende rock, in so great a number of instances between this point and South Vernon that it attracted particular attention. It was found to pass in every case up into the common dark gray mica schist, and to differ from it only in the entire absence of coaly matter and magnetite; and it seems possible that the former may have been discharged by the ferruginous matter of the hornblendic band adjacent. It is, however, wanting below the hornblende bands which rest directly on the dark gray and finer mica schist. This makes it probable that none of the hornblende bands are overturned.

The schists of the area just described are cut off, going eastward, by a great drumlin, though the quartzite can be followed by the north end of it; beyond one finds sections which expose the whole thickness of the schists and hornblende bands.

They are best studied in the area east of the Purple blind road—see map—where, commencing in the chestnut woods northeast of the end of the road, at the basal conglomerate, we pass south over a broad area of the lowest mica schist, broad because of the low dip, and come upon the lowest hornblende rock, a band—about four meters thick—here, as always quite ferruginous and pyritous. Fifteen meters beyond there is a second bed of hornblende rock like the first, and both are capped by the white mica schist layer described above. Going on twenty meters to the top of the ridge, at a large chestnut tree conspicuous in the open field, there is a third rudely laminated layer of hornblende rock, thicker than the others and distinctly laminated. This is capped by a bed one meter

* This Journal, III, vi, 342, 1873.

thick, of a very rusty limestone, carrying abundantly light colored garnet, in large shapeless masses, and light green pyroxene. A long slope follows with scanty outcrops of mica schist, still fine-grained and without staurolite, but with no trace of hornblende; and, at its foot, succeeds a heavy bed of hornblendic rock about twenty meters thick, which by the quite abundant development of feldspar is in large part a complete *quartz-diorite.* Except for the appearance of feldspar, in small irregular white spots, it does not deviate from the usual type of the hornblendic rock of the area. It is followed almost immediately, though the exact contact could not be found, by a bed about fifteen meters thick, of a fine-grained granitoid quartzite, which is indeed, in its whole extent, a *complete granitoid gneiss*, never fissile, and faintly laminated only by the parallel arrangement of the biotite, or wholly lacking this even, and becoming a fine-grained tough *granite, largely feldspathic*, and with many streaked cleavage surfaces, and light gray from the small amount of the biotite. It can be followed here for a long distance, breaking off against a fault in the northeast direction, and going southwest, across Dry brook. Its place between the two heavy hornblende bands seems to be taken by a very fine-grained massive quartz rock, with abundant fine scales of muscovite, and with large round plates of biotite set at every angle. It appears again farther northeast at the last road across the range, and can be followed thence continuously, over the high hill west of South Vernon station and across the plain in Vernon, trending here directly toward the point where the road to Vernon goes beneath the railroad. It is unlike the quartz-conglomerate on the west, and feldspathic quartzite to be described on the east; and conforming in dip and strike with the mica schist, and making all the curves with it, it must be looked upon as a separate band in the mica schist, and cannot well be derived by folding or faulting from the other quartzite.

On the section line it is separated by a small thickness of mica schist from another heavy hornblendic bed, which latter is itself parted by a thin layer of schist, and separated by a heavy bed (30 meters) of a dark gray mica schist, much coarser than the beds below, and carrying abundantly transversely placed biotite, small garnets, and large staurolite crystals, the latter in single crystals, and in twins according to both the common laws. This greater coarseness of the texture, and the great abundance of staurolite in the upper beds of the mica schist, are the rule through the whole length of the range, and militates against any attempt to make out repetitions in the series now gone over. This band is capped by another heavy bed of hornblende rock 20–25 meters thick, which rises in a

prominent ridge overlooking an isolated house (W. Soudin's), and is followed by one more repetition of mica schist, before coming to a fault, upon a broad area of feldspathic quartzite —to be described later—which continues to the railroad at the northwest corner of Gill; and if the section is continued across Grass Hill to the Connecticut river, it cuts first a broad continuation of this upper quartzite, followed by a complete repetition of the mica-schist series, with five hornblendic bands, one feldspathic, and the eastern sloping down the hillside from the Moody school buildings to the river, and thus covering a large area.

Sections carried across the area anywhere from the quartzite base southeastward, give substantially the same succession as that detailed above, only for a distance east of the line there chosen, there is a fault and a repetition of the beds; so that starting from the same point as the one chosen for the beginning of that line, and going directly east, to the saw-mill, on the South Vernon road, nine distinct hornblendic bands are passed, and in almost every case each band is found capped by the whitish schist described above. Also along the State line, and for a distance north and south; either by the thinning of the beds of mica schist or by the slipping of the hornblendic bands over them, the latter are unusually approximated, the three bands below the middle quartzite coming into close proximity to each other, and with the basal quartzite; it is separated by a broad mica-schist valley from a prominent hornblende-rock ridge, just in the east edge of the woods looking down on South Vernon, which is subdivided by only very thin layers of schist. Still farther east, in the large pasture above the South Vernon Hotel, the beds are greatly faulted as indicated upon the map. It illustrates the abundant faulting of the region that at the two short railroad cuts in these beds there are in each case two marked faults, bringing quite distant beds into contact.

Just south of the South Vernon station nearly horizontal mica schist is faulted, on the north, against a dike like mass of hornblende rock, about 10 meters wide; and on the south, an equally distinct east-west fault-line separates the latter rock from the feldspathic quartzite, also nearly horizontal.

At the next cutting, three miles farther north, near where the road crosses the railroad, one band of the hornblende rock is pushed over another and the quartzite over both, so that they have a common dip of 25° S. 65° E.; but the fault planes are distinctly visible, and both the hornblende rock bands are capped by the whitish schist layer which marks their transition into the common mica schist.

The type of the hornblende rock, as seen in the area described above, and in many bands stretching across the country to South Vernon, a type from which there is little variation, is a dark gray to black, fine grained, wholly massive rock, *resembling* so exactly, especially in its jointing, *an intrusive diorite*, that it was connected with the Mesozoic diabase in the first work of President Hitchcock, and the occurrence of it faulted between mica schist and quartzite at the South Vernon station, was called trap, by so experienced an observer as Professor C. H. Hitchcock in his latest work on the area.* The hornblende is generally arranged in fibrous radiated tufts, just visible with the lens, which aids in giving the rock its great toughness. It is not prone to weathering, and stands up generally in long ridges, the schists having been considerably lowered on either side of it, but at the railroad cutting in South Vernon, its fissures were coated with an abundant deposit of calcite and pyrite.

Because of its position in the hollows between the hornblende ridges, the mica-schist, which really occupies much more of the surface than the former, seems, on casual inspection, to be of subordinate extent and importance.

The thickness of the beds, calculated on the average dip of 22° is, quartzite 107 meters, mica schist 113 meters, hornblende rock 158 meters; which is certainly far too large judging from the long line of outcrops farther northeast, and it is probable that each is partially repeated several times by cross faults.

I have elsewhere suggested that hornblende bands of this type are generally derived from limestone beds, and in fact the hornblende bands are still locally quite rich in carbonates, as at the locality first described above just east of Fall River, the broad hornblende band contains layers of limestone 20–30^{mm} thick; and farther northeast, at a large chestnut tree east of the end of the Purple blind road, there occurs in the same association a bed nearly a meter thick of impure limestone carrying garnet and pyroxene.

The development of hornblende at the upper surface of the crinoidal bed has been detailed above, and the large development of hornblende in the quartzite in South Vernon points in the same direction. The hornblende derived from calcite has always a very low absorption.

The feldspathic Quartzite.—Reserving the question of the identity of this rock with the basal conglomerate, I may first call attention to its curious distribution on the map. It occupies a broad area along the eastern border of the schist series, dips everywhere away from it to the eastward with apparent

* Geol. N. H., ii, 438.

conformity, makes the same folds with it all the way from the State-line, south to the point where the main South Vernon-Bernardston road crosses the railroad, even swinging round to a N.–S. strike where the schists do. Beyond this point it occupies a broad area stretching from the railroad across to the Purple blind road, and is plainly separated from the schists on the north by a curvilinear fault. Thence it continues in a broad band southeastwardly, a long distance, and can be followed in scattered outcrops across the sand plains into the town of Gill. Beyond Dry Brook it seems to regain its conformity with the schists. Across the narrow neck by which the West Northfield sands join those of Bernardston, the same quartzite reappears in the northwest shoulder of Grass Hill, and is apparently continuous under the sands with the larger area west of the railroad. It dips under the hornblende rock to the east.

It is everywhere a fine grained light gray fissile quartzite, with small fresh feldspar crystals porphyritically disseminated in it, often quite abundantly. These reach 1–2^{mm} in cross-section, are often but not always striated. They are much larger than the quartz grains and have often sharp crystalline outlines.

In the area south of the great fault at the Purple blind road, and far west from here, it is marked by the abundance of the grains of lavender quartz included in it, which appear to have come from the Archæan gneiss of the Green Mountains. Muscovite, so abundant in the lower quartzite, is wholly wanting; rarely a small amount of biotite in fine scales, or, at one outcrop, of hornblende in scattered needles appear.

The dips of the rocks and of the slates below are so low, and, with the strike, vary so rapidly and irregularly within narrow limits, that I am left in slight doubt as to the exact conformity of the two for any long distance. Going north or south from the northern road over the range, along the line of junction for two miles, no contact of the two could be found, but in the whole distance they seem exactly conformable, and to have shared all minor disturbances together; for instance, although the rocks are tilted so that they strike N. 65° E. and dip 40° S.E., they have also been subjected to an E.–W. thrust, as is seen on a large scale farther south, so that small portions placed irregularly among the rest have a N.–S. strike, which is shared by both the schists and the quartzite.

The basal conglomerate often blackened by argillitic material is a rock of very different habit from this fine grained biotitic feldspathic quartzite; but the description above given of the passage of the beds across Vernon indicates that the former passes into the other going eastward beneath the schists

and is then brought up by a fault along the eastern base of the schist series, and in places thrust over the latter in apparent conformity. The fault line must be an exceedingly tortuous one, and on the east the Grass Hill series must be a repetition of the West Northfield series.

The Bernardston Series east of the Connecticut.—The adjoining area east of the river in Northfield, is unfortunately so covered by the terrace sands, that only few outcrops appear. I think that the rocks of the Bernardston series find their eastern limit through the whole length of Northfield, Ewing and Montague, at the foot of the high ground which bounds the Connecticut Valley on the east; that it ends without any marked shore deposit; but with great crushing of the fine quartzite, probably on a fault of great magnitude and extent, and finally that the quartzite schists and amphibolite, which succeed to the east in the Northfield Hills, though presenting some points of similarity with the Bernardston rocks, are to be associated rather with the series which lies west of the argillite and which are presumably older.

The Quartzite in Northfield.—North of this village, a porphyritic quartzite identical with the eastern band in the West Northfield range, crops out along the eastern edge of the high terrace, but is immediately followed on the east by an older series mentioned above. It is much brecciated and abundantly cemented by hematite. It appears also in the brook bottoms; and just over the line in Winchester, a shaft has been sunk a hundred feet in it for lead, which appears very sparingly in narrow interrupted fissures of a few millimeters width, associated with barite and fluorite in equally small quantities, and at the bottom with beautiful druses of pale yellow, saddle-shaped, dolomite crystals. Below the surface the quartzite is snow-white, but otherwise unchanged. The rock is a hard white saccharoidal sandstone, regularly porphyritic with small clear feldspars in stout rectangular cross sections for the most part striated, and plainly of secondary growth since they enclose sand grains. It is here everywhere massive. Outcrops are seen in all brook beds in the north part of the town, and it approaches nearest to the older series, in a lane running east from the Moody homestead and along the Winchester road. It is here greatly brecciated and full of quartz and hematite veins. On the east of the boundary line several bands of the older series abut obliquely against this line, so that the quartzite on the west rests in manifest discordance, either due to unconformability or faulting against the older series.

The Mica Schist east of the Connecticut River in Northfield.—East of the river only a single limited outcrop of mica schist occurs, a half mile below the village, just opposite Grass

Hill, and 200 rods from the nearest outcrop of hornblende rock, on the west side of the river. It agrees in texture with the lowest beds of schist on the west of the Connecticut, is fine grained, and carries few accessions. It abounds in flattened cavities, which seem to be the obscure traces of fossil shells, but they are wholly indeterminable, if indeed they be of organic origin at all. Upon the joint faces are abundant weathered crystals of a flesh colored zeolite, apparently chabazite. The exact locality is by the brook crossing, at a mill pond near A. Billings'.

Conclusion.

The section below seems to me to represent the succession of the beds represented, the newest above.

1. Mica schist,
2. Hornblende schist,
3. Mica schist,
4. Hornblende schist,
5. Mica schist,
6. Hornblende schist,
7. Mica schist,
8. Quartzite,
9. Hornblende schist and Magnetite,
10. Limestone.
11. Hornblende schist,
12. Quartzite conglomerate,
13. Argillite,
14. Calciferous mica schist.

Originally heavy beds of shale (*a*) graduated upward into a great series of feldspathic sandstones (*b*) and conglomerates, which contained a band of crinoidal limestone with a local development of iron ore near its surface. Above this was an extensive series of shales (*c*) with several intercalated beds of impure limestone. The first series has changed into a crumpled and cleaved phyllite to which the name argillite has been for a long time appropriated. The second series has passed through all the changes to a gneiss so complete that Professor Hitchcock insists on associating it with the Bethlehem gneiss—quartzite with flattened pebbles, muscovite quartzite, biotite quartzite, feldspathic quartzite often porphyritic, and complete biotite gneiss often becoming chloritic from superficial change.

The limestone has become most coarsely crystalline and the lime and iron have been carried far out into the quartzites above and below to form hornblende schists and complex hornblende-chlorite pyrite rocks.

The iron ore forms a bed of magnetite or a magnetite rock.

The upper series is changed to complete mica-schists spangled with transverse biotite crystals, often loaded with garnets and staurolites; while the limestone beds are changed from the surface toward the center into hornblende schist beds abstracting the iron from an adjacent band of the shales.

The dips are all to the east and the beds are several times repeated by monoclinal faulting and with each reappearance of the quartzite it is finer grained and more feldspathic.

The whole series has a slight pitch to the south, so that in Vernon the whole upper series tapers northward and disappears; and then in going eastward from the argillite we pass from the more quartzose conglomerates through muscovite and biotite quartzites to complete gneisses, as in the successive reappearances farther south.

The most abundant and characteristic fossils are Chemung with several Hamilton forms, so that the limestone, magnetite, and the base of the quartzite above the limestone may be placed with certainty near the base of the Chemung. That the whole series must go together is, I think, clear from the map and the preceding discussion. The suggestion of Professor Hitchcock, that the limestone was bounded on both sides by faults* prove true for the west side, but is not true for the east side, and the important deduction made by him that the limestone was greatly newer than all the surrounding rocks is also disproved.

The argillite, though the oldest rock, is least decomposed, crumpled and cleaved with dull surfaces and full of coal grains and kaolin, in its most eastern exposures showing minute pustules on its slaty surfaces, and at last developing garnet and biotite in some abundance. In the western exposures of the mica-schist series, kaolin could scarcely be detected, and biotite, garnet and staurolite were quite abundant, but almost microscopic, while farther east the surfaces show clearly the muscovite sheen, and the above accessions are abundant and large. In the calciferous mica schist which lies below the argillite the separate muscovite scales are clearly visible to the eye, and the same accessories occur still larger and with a very different and much more complex structure.†

* 15, p. 315.

† The note in the former part of this paper at the foot of page 264 should be transferred to page 266. It applies to figure 2.

Art. XLVII.—*Analysis of Rhodochrosite from Franklin Furnace, New Jersey;* by P. E. Browning.

The specimen of rhodochrosite, an analysis of which is here given, was collected for the Yale Museum some two or three years since and was furnished to writer for examination by Professor E. S. Dana. It has a massive, cleavable structure and a bright pink color. Franklinite and willemite are immediately associated with it. The method of analysis was, as follows:

A portion of the mineral was dissolved in hydrochloric acid, evaporated to dryness to separate any silica present. The filtrate from silica was treated either with sodic acetate or ammonium hydrate and the iron separated and weighed. After the separation of the iron, the zinc was precipitated as sulphide by hydrogen sulphide in acetic acid solution. The filtrate from sulphide of zinc was treated with bromine water, by which method the manganese comes down as black oxide. In two determinations ammonia was used with the bromine water to bring about the same result. In all these cases the black oxide was dissolved and reprecipitated to avoid any holding back of lime. The black oxide in every case was dissolved by sulphurous and hydrochloric acids, precipitated as phosphate and weighed after ignition as pyrophosphate according to Gibbs's method. The amount of manganese being large, two direct determinations were also made by Ford's method, which consists in boiling the mineral, after separating the silica, with strong nitric acid and potassium chlorate until green fumes cease to be given off. The black oxide is thus directly precipitated and may be treated as above by Gibbs's method. These results were satisfactory in their agreement. The filtrate from black oxide of manganese was evaporated to about 300 or 400cm^3, made ammoniacal, and calcium precipitated as oxalate, dissolved and reprecipitated in same manner. The filtrate from both oxalate precipitations was evaporated (and in two cases the residue was ignited to free it from great excess of salts of ammonia) and precipitated as phosphate, dissolved in hydrochloric acid, and reprecipitated in same manner with ammonia and a little hydrodisodic phosphate, ignited and weighed as pyrophosphate. Each element was determined at least three times. Five determinations of manganese were made. Two analyses of the mineral were carried through in platinum dishes to avoid any contamination by silica in glass or porcelain. The amount of iron in ferrous condition was determined by dissolving a portion of mineral in sulphuric

acid and titrating with a standard solution of potassium permanganate. Three determinations of carbon dioxide were made taking 0·5 gram portions, and a fourth in which 2 grams were used agreed closely with the others. In these determinations the carbon dioxide was set free in suitable apparatus by the action of hydrochloric acid and heating, and weighed after absorption in potassium hydrate. The analysis is as follows:

Specific gravity = 3·47.

MnO	45·02 per cent.
CaO	11·28
ZnO	2·32
MgO	1·76
FeO	0·22
Fe_2O_3	0·16
SiO_2	0·32
CO_2	38·94
	100·02 per cent.

The presence of silica suggested the possible presence of zinc silicate (Zn_2SiO_4) as impurity; accordingly there was deducted from the ZnO found enough to balance the silica, and the remaining constituents were calculated to one hundred per cent. The result is given in I below.

I.		II.	
MnO	45·55 per cent.	$MnCO_3$	73·78 per cent.
CaO	11·41	$CaCO_3$	20·37
ZnO	1·48	$ZnCO_3$	2·28
MgO	1·78	$MgCO_3$	3·74
FeO	0·22	$FeCO_3$	0·35
Fe_2O_3	0·16	Fe_2O_3	0·16
CO_2	39·40		
	100·00		100·68

The hypothetical composition of the mineral, calculating the bases as carbonates, is given under II above. It will be seen that the amount of acid (CO_2) required to supply the bases exceeds the amount found by 0·68 per cent. The ratio of Mn : Ca : Mg = 6·4 : 2 : ·44.

In concluding this paper, the writer would express his appreciation of the valuable advice obtained from Professor Gooch during the progress of the analysis.

Kent Laboratory, Yale University, July, 1890.

Art. XLVIII.—*A Re-determination of the Atomic Weight of Cadmium;* by Edw. A. Partridge, M.A., B.S.

The atomic weight of cadmium has been determined by Stromeyer, Von Hauer,* Lenssen,† Dumas‡ and Huntingdon.§ With O=16 for the basis of calculation the values obtained by these experimenters are the following: by Stromeyer 111·48, by Von Hauer 111·96, by Lenssen 112·08, by Dumas 112·25, by Huntington 112·24. From these results Clarke calculates 112·092 to be the most probable figure, and concludes his article on the subject with this remark: "It will be seen that Dumas's and Huntingdon's determinations both made with haloid salts of cadmium agree with wonderful closeness and so confirm each other. On the other hand, Von Hauer's data give a value which is much lower. Apparently Von Hauer's method was good, and the reason for the discrepancy remains to be discovered. Until that is ascertained, I prefer to use the above mean value rather than to adopt one investigation and reject the others."

This investigation was undertaken with the hope of arriving at a value for the atomic weight of cadmium more reliable than that given by former experimenters.

The following points were regarded as of first importance:

1st. The most scrupulous care in the purification of the materials used in every stage of the work.

2d. Avoidance of any method in which the reactions involved were uncertain or doubtful.

3d. The utmost care and refinement in weighing.

4th. Use of a large number of determinations as the basis of calculation.

At the outset much time was devoted to making a pure cadmium salt by recrystallization of the sulphate, and much work was devoted to accumulating a stock of this as the starting point. This, however, was discarded in favor of the metal obtained by distillation.

The literature upon this subject is interesting, though somewhat meager. Mercury has been purified by distillation for years. Demarçay‖ in 1882 observed that zinc and cadmium are volatile in vacuo at comparatively low temperature, and suggests this as a means of purification. In 1884, Schuller¶

* Jour. für Prakt. Chemie, xxii, 350.
† Ibid., lxxix, 281.
‡ Ann. Chem. Pharm., lxiii, 27.
§ Proc. Amer. Acad., 1881.
‖ Comptes Rendus, xcv, 183.
¶ Ann. d. Phys., xviii, 320, and Jahresbericht 1884, 1550.

stated that zinc and cadmium can be distilled in vacuo, leaving the impurities as a residue. This method has been employed by Morse and Burton* for the purification of zinc. One of the means employed by Stas in his classical investigation upon atomic weights was the purification of silver by distillation. Whenever available, distillation ranks first among the processes for purification at the disposal of the chemist. This was affected in the case of cadmium in tube retorts of glass, about 30^{cm} in length and $20–25^{mm}$ in diameter.

The tubes were closed at one end and drawn down at a point about 11^{cm} from the closed end, making a neck about 12^{mm} in diameter. 100 grams of cadmium having been introduced, the open end was drawn down to a size suitable for a connection with the mercury pump. The portion of the tube between the neck and the end connected with the pump serves to condense and retain the distilled metal.

After having been supported on a combustion furnace, the retort was exhausted as completely as a rapidly acting three-fall mercury pump would effect in one hour. The gauge, then standing only a fraction of a mm. lower than the barometer. As the pump was self-acting this degree of exhaustion was readily maintained during the entire operation. Heat was then slowly applied and so managed that the greater part of the metal condensed and ran down the sides of the retort, only the more volatile portion passing beyond the neck of the tube. A fractional distillation was thus effected, cadmium alone passing over. In an hour 60 grams of cadmium had collected in the receiver, the distillation was then stopped and when entirely cold the metal was removed by cutting open the tube. The greater part of it collected as a bar at the bottom of the receiver, while the sides and top were lined with crystals, many of which were quite perfect. The residue in the retort was covered with a brownish black scum, which was tested spectroscopically and found to consist mainly of lead, iron and thallium, with a little copper. The lines of zinc were once very faintly seen.

The cadmium thus purified was distilled a second time in the same manner. The residue from this distillation, which was pushed no further than the first, remained perfectly bright to the end and when tested with the spectroscope did not reveal a trace of foreign metals. All the cadmium used in this investigation was thus purified by double distillation.

One of the methods used for the determination of the atomic weight of cadmium is that of Lenssen which, although good, was merely touched upon by him. His result was based upon only three experiments, using very small quantities of material.

* Amer. Chem. Jour., x, 311.

The method consists in changing cadmium oxalate to cadmium oxide, and observing the loss of weight from which loss the atomic weight is calculated.

For working this method cadmium oxalate was made as follows:

The perfectly pure metallic cadmium obtained by double distillation was dissolved in pure nitric acid, prepared by careful distillation, and the solution concentrated so far that on cooling the cadmium nitrate $Cd(NO_3)_2+4H_2O$, separated in long fibrous crystals. The latter were drained at the filter pump, dissolved in water, and a solution of the theoretical amount of pure oxalic acid added. Cadmium oxalate thus prepared is a heavy crystalline precipitate which can be easily washed. This was done several times by decantation. The precipitate was then placed on a filter and washed at the pump thirty times with distilled water, after which it was dried for 10 hours at 150° C. The salt thus obtained was tested for nitric acid by the phenol test and showed not the slightest trace. The pure cadmium oxalate thus obtained was subjected to the following treatment:

About one gram of cadmium oxalate was placed in a porcelain crucible and was then dried in an air bath at 150° C. for five hours. This length of time was usually sufficient to dry the salt completely. When this had been accomplished, i. e., when a constant weight had been attained, the crucible containing the oxalate was covered with a watch glass and very cautiously heated. This operation required the greatest care, since if the temperature became too high, reduction and consequent volatilization of metal occurred. Four of the earlier experiments were lost in this way. That volatilization of metal had taken place was made evident by a slight sublimate on the watch glass. When the oxalate was completely decomposed (this was shown by the uniform brown color of the resulting cadmium oxide) it was allowed to cool and moistened with a few drops of nitric acid in order to re-oxidize any reduced metal. The nitric acid employed for this purpose was especially purified by very careful distillation. Ten c. c. of it evaporated in a platinum dish left a visible but imponderable residue.

The crucible was then very carefully ignited until all the cadmium nitrate was decomposed, then placed inside a nickel crucible 4^{cm} high by 4^{cm} wide and strongly ignited for half an hour by means of a Fletcher's improved Bunsen burner. In all cases the ignition was repeated until a constant weight was obtained. There was rarely, however, any loss of weight after the first ignition. To prevent the possibility of any reducing gases reaching the cadmium oxide, the nickel crucible inside

which the porcelain crucible was placed, was forced into a circular hole cut in a piece of asbestos board 13^{cm} square. The top of the nickel crucible was flush with the upper surface of the board, the joint being air tight.

Ten experiments made by the above method gave the following results:

SERIES I.

	Weight of cadmium oxalate taken.	Weight of cadmium oxide found.	Atomic weight.
1	1·09898	·70299	111·819
2	1·21548	·77746	111·793
3	1·10711	·70807	111·755
4	1·17948	·75440	111·780
5	1·16066	·74237	111·783
6	1·17995	·75471	111·784
7	1·34227	·85864	111·829
8	1·43154	·91573	111·823
9	1·53510	·98197	111·821
10	1·41311	·90397	111·834
Total	12·66368	8·10027	(111·8027)

Mean value	111·8027
Maximum,	111·834
Minimum	111·759
Difference	·075
Probable error	·010

Another method used for the determination of the atomic weight of cadmium is that of Von Hauer. It consists in reducing cadmium sulphate to cadmium sulphide in a stream of hydrogen sulphide and observing the loss of weight. As the result obtained by Von Hauer is considerably lower than those obtained by other experimenters, doubt has been cast upon its accuracy. The following possibilities have been suggested as tending to make Von Hauer's results low: 1st. That the cadmium sulphate as weighed by him contained hygroscopic moisture. 2d. That the presence of metallic iron in the ferrous sulphide used in making the hydrogen sulphide would lead to the generation of hydrogen and consequent reduction and volatilization of cadmium. 3d. That some cadmium sulphide might have been volatilized in the stream of hot hydrogen sulphide.

It was, therefore, determined to carry out a series of experiments by this method in order to determine if any of these objections were well grounded.

In the experiments about to be described, the first danger was overcome by weighing the sulphate in stoppered glass

tubes. The second was shown to be groundless, as in some experiments the hydrogen sulphide used was prepared from antimony trisulphide and in others from ferrous sulphide with perfect agreement of results. The third objection was disproved experimentally, as the highest heat that hard Bohemian glass will withstand did not cause any volatilization of cadmium sulphide. That there was no volatilization of sulphide was proved by the weight of a sample of the same which was heated in a stream of hydrogen sulphide to the extent just mentioned, remaining absolutely constant, and also by the fact that there was not the slightest sublimate on the tube.

The hydrogen sulphide employed in this and in the following series of experiments was washed by passing it through water and dried by passing through a long calcium chloride tube. The carbon dioxide was dried by passing through a wash bottle containing sulphuric acid and then over calcium chloride By means of a three-way cock the carbon dioxide could be run into the apparatus without changing the connections.

The cadmium sulphate was prepared in the following manner: Cadmium nitrate, prepared as above described, was dissolved in water and a slight excess of pure sulphuric acid added. Five c. c. of this acid were evaporated in a platinum dish, leaving a visible but imponderable residue.

The solution was evaporated to dryness in a platinum dish and heated long after fumes of sulphuric acid ceased to come off. The sulphate was dissolved in water, recrystallized and dried for six hours at 200° C.

The following is a description in detail of the method used in the experiments, the results of which are tabulated below. (Series II.)

The dry cadmium sulphate was placed in a porcelain boat and heated for some time in an air bath to about 300° C. While still warm the boat was placed in the weighing tube, allowed to cool and weighed. Cadmium sulphate parts with its hygroscopic moisture very readily at 300° C. After weighing, the boat containing the cadmium sulphate was placed in a hard glass tube, 50^{cm} in length, supported over a small combustion furnace. A stream of pure dry hydrogen sulphide was then passed through the tube and heat applied. It was heated moderately for 45 minutes and to dull redness for as much longer. By this time its reduction to sulphide was always complete. It was then allowed to cool to about 200° C. in a slow stream of the gas. When the temperature had fallen to this degree the hydrogen sulphide was displaced by a stream of pure dry carbon dioxide, and while still warm the boat containing the cadmium sulphide was placed in the weighing tube,

allowed to cool and weighed. Ten experiments by this method gave the following results:

SERIES II.

	Weight of cadmium sulphate taken.	Weight of cadmium sulphide found.	Atomic weight.
1	1·60514	1·11076	111·793
2	1·55831	1·07834	111·789
3	1·67190	1·15669	111·790
4	1·66976	1·15554	111·818
5	1·40821	·97450	111·801
6	1·56290	1·08156	111·806
7	1·63278	1·12985	111·778
8	1·58270	1·09524	111·797
9	1·53873	1·06481	111·796
10	1·70462	1·17962	111·801
Total	15·93505	11·62717	(111·7969)

Mean value	111·7969
Maximum	111·818
Minimum	111·778
Difference	·040
Probable error	·008

In the course of the work the experiment of passing hydrogen sulphide over gently heated cadmium oxalate was tried. This salt was completely transformed into the sulphide at a temperature much below that which is necessary for its conversion into cadmium oxide. This reaction was then made the basis of a new method for the determination of the atomic weight of cadmium. The method used in the ten experiments, the results of which are given below (Series III), was as follows:

Cadmium oxalate was placed in a porcelain boat and dried at 150° C. to a constant weight. It loses all of its moisture at that temperature. While warm the boat was placed in the weighing tube, allowed to cool and weighed. The boat containing the cadmium oxalate was then placed in a tube arranged for passing hydrogen sulphide and supported over a combustion furnace as above described. The reducing gas was passed through the tube and heat slowly applied. When the contents of the boat had been completely changed to sulphide, the heat was raised to incipient redness and kept at that temperature for about one hour. The cadmium sulphide was allowed to cool to about 200° C. in a slow stream of hydrogen sulphide which was then displaced by a stream of pure dry carbon dioxide. While still warm the boat containing the cadmium sul-

phide was placed in the weighing tube, allowed to cool and weighed. In every case the sulphide was reheated in the stream of hydrogen sulphide. There was never any volatilization of cadmium sulphide, as the weight always remained the same, although in some experiments the sulphide was heated three times as long as in others. Moreover there was never any sign of volatilization either on the boat or on the tube. Ten experiments by the above method gave the following results:

SERIES III.

	Weight of cadmium oxalate taken.	Weight of cadmium sulphide found.	Atomic weight.
1	1·57092	1·13065	111·812
2	1·73654	1·24979	111·786
3	2·19276	1·57825	111·824
4	1·24337	·89492	111·823
5	1·18743	·85463	111·807
6	1·54038	1·10858	111·771
7	1·38905	·99974	111·806
8	2·03562	1·45617	111·833
9	2·03781	1·46658	111·774
10	1·91840	1·38075	111·814
Total	16·85228	12·12906	(111·8050)

Mean value	111·805
Maximum	111·833
Minimum	111·771
Difference	·062
Probable error	·009

The mean of the three series gives 111·8015 as the atomic weight of cadmium, with O = 16.

The following is a description of the methods and apparatus used in the weighings: In the experiments by Lenssen's method two crucibles were used, one as a counterpoise. This dummy was treated in every respect in the same manner as the crucible containing the material operated upon. For weighing the crucibles, small beakers, with glass covers ground on, were provided. These beakers were adjusted so that their weights were approximately equal. The balance being provided with two riders, one of them was used to obtain adjustment with the beakers on the pans, while the other was used in the actual weighing after the crucibles were introduced. The beakers were never touched with the hands, but were taken in and out of the balance case by means of tongs, and the crucibles were introduced into the beakers with platinum forceps. The adjustment of the balance with the beakers on the pans was tested

before and after every weighing, and during the entire series of experiments the greatest variation was ·0001 grams.

For weighing the boats used in the second and third series of experiments, light glass tubes, with accurately fitting stoppers of glass, were made. Two boats were used in every experiment, one as a counterpoise. The boats, while still warm, were placed in the tubes and the tubes stoppered. When quite cold the stoppers were momentarily loosened to restore the atmospheric equilibrium inside the tubes.

The balance used was most accurate and highly sensitive, of the short arm pattern, with an aluminium beam. With a load of 30 grams in each pan the resting point was displaced two whole divisions by ·0001 grams. The weights were adjusted with the utmost care, especially for this work. The weighings in all experiments were reduced to the vacuum standard.

University of Pennsylvania.

ART. XLIX.—*On the occurrence of Nitrogen in Uraninite and on the composition of Uraninite in general. Condensed from a forthcoming Bulletin of the U. S. Geological Survey;* by W. F. HILLEBRAND.

THE following pages contain in much condensed form the results of chemical work thus far done by myself on uraninite from various localities in North America and Europe, of which brief notices have already from time to time appeared.* For various reasons it has been impossible to bring the investigation as far forward as was expected, and the results are in some respects incomplete and in others difficult of interpretation, but so much time has elapsed since the work was begun that it seems advisable to make public now what has been achieved, without waiting an indefinite and probably long time for the sake of then presenting the subject in a more finished and satisfactory form.

At an early stage of the work it was found that to the North American varieties could by no possibility be applied the formula obtained by Comstock† for the Branchville Conn., mineral, and by Blomstrand‡ for the Norwegian and Bohemian varieties. Comstock's analysis was shown to be incorrect, he having found no thoria where about 7 per cent

* This Journal, III, xxxvi, 295, xxxviii, 329, and Bull. U. S. Geol. Survey, No. 60, p. 131.

† This Journal, III, xix, 220.

‡ Geol. För. Förh., vii, 59, and Journ. prakt. Chem., xxix, 191.

existed and his UO_2 being moreover much too low. A re-examination of the Norwegian mineral seemed desirable, and thanks to Professors W. C. Brögger and A. E. Nordenskiöld, who kindly furnished material from several quarries about Moss and from Arendal, this was rendered possible. The results were surprising and established beyond question that the formula found by Blomstrand was purely accidental, that the mineral from different quarries varied in composition and in such a manner that it was inadmissible to suppose that the occurrence analyzed by him represented the pure material from which the others might have been derived by alteration. The most surprising discovery, however, was that nitrogen is an integral component of most uraninites and possibly of all, in quantities ranging from mere traces up to over 2·5 per cent.

The nitrogen is set free from the mineral as nitrogen gas by the action of a non-oxydizing inorganic acid, and by fusion with an alkaline carbonate and probably also caustic alkalies in a current of CO_2. As obtained by the use of acids the gas is colorless, odorless, a non-supporter of combustion, unchanged by mixture with air, neutral to litmus papers, not absorbed by caustic alkalies, and insoluble in water, at least its coefficient of absorption is so small as to be inappreciable without elaborate experimentation. When subjected in a eudiometer to the ordeal prescribed by Bunsen * there results no alteration in volume, other than that caused by the union of the hydrogen and oxygen added.

This evidence, while fairly conclusive as to the nature of the gas, was purely negative, and proof of a more positive character was sought. Nitric acid is formed from a moist mixture of the gas with pure oxygen by long continued passage of the electric spark, and ammonia is produced by the so-called silent discharge through a mixture of the gas with three volumes of electrolytic hydrogen. The contraction produced in the latter case could be measured by cubic centimeters, and water used as an absorbent of the ammonia colored red litmus paper deep blue, besides giving a strong ammonia reaction with Nessler's reagent. With dilute hydrochloric acid as an absorbent there was obtained an abundant precipitate of ammonium platinic chloride. In a Geissler tube under a pressure of 10^{mm} and less the gas afforded the fluted spectrum of nitrogen with great brilliancy.

Special attention was paid to the estimation of UO_3, or more properly of the oxygen required to effect complete oxidation after solution of the mineral in sealed tubes with sulphuric acid. It was found that concordant results were only to be obtained when the tubes were filled with CO_2 from

* Gasometrische Methoden, 2d ed., pp. 73 and 74.

a generator and not by the introduction of Na_2CO_3 into the tubes themselves. With the observation of this and other precautions detailed in the unabridged article the results of titration with $KMnO_4$ leave nothing to be desired as regards accuracy.

The analyses which follow were with two exceptions—V and XVIII—made before recognition of the nature and importance as regards quantity of the gas given off by acid, and their object was chiefly to ascertain the relative percentages of UO_2, UO_3, and rare earths with a reasonable degree of closeness. Unusual pains to secure very accurate summations were therefore not taken except in analysis V, and this was unfortunate as will appear later.

Comstock and Blomstrand both assumed that the iron found by them existed as FeO, but for reasons which cannot be

North American Uraninites.

	Connecticut.										
	Glastonbury.					Branchville.			Colorado.	North Carolina.	
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
UO_3	22·08	23·35	22·22	26·48	23·03	13·27	21·54	14·00	25·26	50·83	44·11
UO_2	59·13	58·01	59·31	57·43	59·93	72.25	64·72	70·99	58·51	39·31	46·56
TiO_2									trace.		
ZrO_2?							·33		7·59		
ThO_2		9 78		9 79		7·20	6·93	6·52		2·78	
CeO_2	9·57		10·31	·25	11·10				·22	·26	3·04
$(La,Di)_2O_3$				·13						·50	
$(Y,Er)_2O_3$		·46		·20						·20	
Fe_2O_3	1·21	·33	·67	·40	.29	·11	·28	·27		trace.	
PbO	3·14	3·24	3·07	3·26	3.08	4·35	4·34	4.35	·70	4·20	4·53
ZnO									·44		
FeO									·32		
MnO				trace.		·10	·07	?	·16		
CaO	·08		undet.	·08	·11	·18	·22	·30	·84	·85	·23
MgO								·15		·30	·25
Alk.											
H_2O	·97	undet.	undet.	·61	·43	·68	·67	·68	1·96	1·21	undet.
N	undet.	undet.	undet.	undet.	2·41	undet.	undet.	2·63	·15	·37	undet.
SiO_2	1·06		·25	·16	·16	·03	·13	·20	2·79	·08	·13
P_2O_5					·02				·22	?	
As_2O_5									·43		
Fl					·04						
$CuFeS_2$									·12		
FeS_2									·24		
Cb_2O_5	·96										
Insol.	·85	1·74	·42	·70	·89	·04	·14	1·40		·10	·06
Total	99·05	96·91	96·25	99·49	101·49	98·21	99·37	101·49	99·95	100·99	98·91
Sp. G.	9·139	9·051		9·587	9·622	9·733	9·560	9·348	8·068	9·086	9·492

detailed in this paper I have preferred to consider it generally as Fe_2O_3. The values given for UO_3 and UO_2 are therefore subject to a correction if this assumption should prove unwarranted, but the amount of iron found is so small as to affect in no way the conclusions drawn from the analyses. It is highly probable from an experiment made on the material of analysis V that none of the iron belongs to uraninite, but is simply derived from foreign bodies from which it is practically impossible to free the mineral entirely. It is probable that in all cases but V and XVIII the total percentage of earths is somewhat too low. Oxalic acid always leaves a portion of the earths with uranium, and the remainder can only be recovered by precipitation as nitrates by ether from a neutral solution. This was done only in the two cases mentioned, which in point of time post-date all other analyses.

Norwegian Uraninites.

	Anneröd.	Elvestad.	Elvestad.	Skreatorp.	Huggenäskilen.	Arendal.	Arendal.
	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
UO_3	30·63	25·36	22·04	32·00	35·54	41·71	26·80
UO_2	46·13	50·74	43·03	43·88	43·38	24·18	44·18
ZrO_2?	·06	·08					
ThO_2	6·00	8·48		8·98	6·63		4·15
CeO_2	·18	·21	8·43	·17	·20	3·66	none
$(Di,La)_2O_3$	·27	·26		·36	·23		·67
$(Y,Er)_2O_3$	1·11	1·10		·97	1·03	9·76	9·05
Fe_2O_3	·25	·21	·30	·09	·32	·03	·24
PbO	9·04	10·06	8·58	9·46	9·44	10·54	10·95
MnO		·06					
CaO	·37	·77	·37	·36	·41	1·06	·61
MgO	trace.	trace.	·13	trace.	·13	·10	·04
Alk.						·23	·15
H_2O	·74	·73	·74	·77	·79	1·23	undet.
N	1·17	1·28	1·08	1·03	1·08	undet.	1·24
SiO_2	·22	·38	·29	·53	·49	·90	·50
P_2O_5	·02	·04	trace.	?	trace.		trace.
Insol.	4·42	·45	15·45	1·54	·42	1·10	1·19
Total	100·61	100·21	100·44	100·14	100·09	94·50*	99·77
Sp. G.	8·893	9·145	8·320	8·966	8·930	7·500	

Want of space forbids reproducing in this article numerous explanatory notes and the separate figures of which the above are in many cases the mean, without which the accompanying tables should on no account be used as a basis for criticism.

The Glastonbury material was all from Hales's quarry in the town of Glastonbury, a few miles N.E. of Middletown, and was obtained through various channels. That from

* The loss in this analysis is supposed to be mainly accounted for by CO_2.

Branchville was received from Professors Brush and Dana, and was the residue of the material from which Comstock had taken his for analysis. No. VI was by far the purest of any material obtained from any locality. It is earnestly to be hoped that more of this excellent material may be found for closer investigation, since it possesses the greatest density and the highest percentage of UO_2 and N of any known variety, besides representing the extreme of perfection as regards crystallization and purity.

The Colorado mineral differs from all other American occurrences in that it is devoid of crystalline form and that thoria is wanting, its place being apparently supplied by zirconia. It moreover contains the least amount of lead of any known uraninite. The North Carolina material was analyzed mainly to learn if rare earths enter into its composition. No. X represents the composition of the purest sample available, and No. XI of the residue after extraction of the yellow oxidation products by very weak HCl. No really unaltered uraninite appears to have been found in North Carolina.

Of the Norwegian specimens those analyzed under XII and XIII were from Professor W. C. Brögger, the remainder from Professor A. E. Nordenskiöld. XII is the original Bröggerite of Blomstrand, while XIII is "so viel ich weiss von derselben Stelle wie das Originalmaterial Lorenzens" (Brögger). Those from Professor Nordenskiöld all bore erroneously, with exception of that from Arendal, the name Cleveite.

In the following table all the foregoing analyses of Norwegian material have been re-calculated to the percentages found, excluding the insoluble matter, in order that their true relations may appear at a glance, whereby the sum of the rare earths combined is given instead of each earth or group of earths by

	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
UO_3	32·04	25·48	26·04	32·50	35·69	42·11	27·12
UO_2	48·25	50·97	50·83	44·57	43·56	24·51	44·71
Earths	7·97	10·18	9·96	10·64	8·12	13·57	14·03
PbO	9·45	10·11	10·14	9·61	9·48	10·66	11·08
CaO	·39	·77	·45	·36	·41	1·07	·62
H_2O	·77	·73	·87	·78	·79	1·23	?
N	1·23	1·28	1·28	1·05	1·08	?	1·26

itself. Only those constituents are tabulated which may be considered unquestionably in whole or in part as belonging to the uranium mineral.

An examination of analyses XII to XVI as re-calculated hardly allows of any other conclusion than that the specimens

from the above four different quarries about Moss belong to one and the same mineral species, just as may be said of the mineral from the two Connecticut localities. While analysis XII differs in some respects from Blomstrand's analysis of Bröggerite it simply serves to show that the mineral may vary in composition in the same quarry. Leaving out of consideration for the present the nitrogen, it is certain that the ortho-uranate formula derived by him from his analysis cannot be obtained from No. XII. A comparison of analyses XIII and XIV with Lorenzen's analysis,* coupled with Professor Brögger's words given above and the fact that not one of the specimens from the neighborhood of Moss above analyzed contains less than 8 per cent of earths, gives rise to the strongest possible suspicion that that analyst has overlooked thoria altogether, notwithstanding the fact that the present material is from Elvestad and Lorenzen's was from Huggenäskilen. The possibility of a mistake as to the source of Lorenzen's material is suggested by the totally different ratio between UO_2 and UO_3 in the specimen from Huggenäskilen sent by Professor Nordenskiöld (No. XVI). If it should prove that Lorenzen overlooked thoria, another of Blomstrand's supports in favor of the ortho-uranate formula for all uraninites, including Bröggerite and Cleveite, is knocked away, the first being the earlier and as shown incorrect analysis of Branchville uraninite.

The oxygen ratios calculated for analyses XII to XVI, counting all earths as thoria, whereby the comparison is very little affected, since the percentages of other earths are almost alike in all analyses, are as given below, as also the ratio for Blomstrand's Bröggerite, in which FeO has been changed to Fe_2O_3 and a corresponding change made in the UO_2 and UO_3 in order to compare properly with the others.

	Mol. Wt.	XII.		XIII & XIV.		XV.		XVI.		Bröggerite.	
UO_3	287	5·36	1	4·31	1	5·44	1	5·96	1	6·07	1
UO_2	271	5·70		6·01		5·26		5·14		5·15	
Earths	266	·96	1·37	1·21	1·85	1·28	1·33	·98	1·14	1·02	1·11
PbO	223	·68		·73		·69		·68		·60	

It is seen that none of the ratios conform even approximately to that for Blomstrand's analysis except that of the mineral from Huggenäskilen. A re-calculation of all with Fe_2O_3 instead of FeO and consequent changes in UO_2 and UO_3, and separation of the earths would give the normal ratio 1 : 1 for Blomstrand's analysis, but the others would differ from it more widely than in the above exhibit.

* Nyt Mag. f. Naturv., xxviii, 249. UO_3 38·23, UO_2 50·42, PbO 9·72, FeO ·25, CaO ·21, H_2O ·70, SiO_2 ·31 (99·84).

The correctness of the ortho-uranate formula for Bröggerite itself having been invalidated by the difference between his own and analysis XII above, it is hardly worth while to discuss its applicability to the Bohemian and Saxon uraninites of which no complete and reliable analyses have been made except perhaps the single one by Ebelmen in 1843, which on re-calculation by Blomstrand was found to conform to his view. It can hardly be doubted that had Blomstrand been able to analyze material from more than one quarry about Moss he would have seen the impossibility of reconciling the discrepancies in composition so as to admit of the application of one general formula.

It is apparent notwithstanding the deficiency of earths and one or two other discrepancies, that analysis XVII was really made upon Cleveite as the label indicated. The density too corresponds exactly with that found by Nordenskiöld.* From a comparison of analyses and reasoning which cannot be here set forth for want of space, it is in the highest degree probable that the Cleveite of Nordenskiöld, the Nivenite of Hidden and Mackintosh,† and the material of analysis XVII are identical or represent slightly different stages of alteration of one and the same original species. What this species is is pretty clearly indicated by analysis XVIII where the earths are in about the same proportion as in XVII, but the UO_3 and UO_2 stand in a very different ratio. The material of this was likewise from Arendal and presumably from the precise locality of that of analysis XVII, since the pieces were in one package without distinguishing labels. Its extreme solubility‡ compared with the other Norwegian uraninites is shared by that of analysis XVII, by Cleveite, and by Nivenite, and is to be explained probably not so much by advanced decomposition as by the preponderance here of a more soluble yttrium-uranium compound. Whether this last Arendal material is the same whence Cleveite and its American representative have been derived by alteration, as seems most probable, or not, it is in any event a true uraninite of more basic character than any of the Norwegian thorium-uraninites, and consequently conforms still less than those to the ortho-uranate formula.

Only traces of nitrogen were found in uraninite from Przibram, Joachimsthal, and Johanngeorgenstadt. None of the specimens contained zirconia, thoria, or other rare earths.

* Geol. För. Förh., iv, 28, and Zeitschr. f. Kryst., iii, 201.

† This Journal, III, xxxviii, 481.

‡ In this connection it may be remarked that the greatest difference exists between the solubility of the Norwegian and the American uraninites. While 12 hours is more than sufficient to effect complete decomposition of any of the former by very dilute H_2SO_4 at 100° C., nine days is insufficient for the Connecticut mineral.

Owing to the uncertainty of being able to determine with any close approach to truth the proportions of UO_2 and UO_3 in the presence of sulphides and compounds of arsenic and vanadium, no quantitative analyses of specimens from those localities have as yet been made.

Hitherto the analyses have been considered without reference to the nitrogen. It has been sought to show on grounds which would be valid even without its presence that the ortho-uranate formula is capable of no general application to uraninite, and that in the one or two cases where it does seem to apply this agreement is probably accidental. Taking into account the low atomic weight of nitrogen as compared with uranium, thorium, and lead, it is plain that it must play an important part in the constitution of the molecule, and that therefore its discovery without other evidence furnished by the analyses is sufficient to invalidate entirely the practically identical formulæ of Comstock and Blomstrand. Throughout the whole list of analyses in which nitrogen has been estimated the most striking feature is the apparent relation between it and the UO_2. This is especially marked in the table of Norwegian uraninites recalculated, from which the rule might almost be formulated that, given either nitrogen or UO_2 the other can be found by simple calculation. The same ratio is not found in the Connecticut varieties, but if the determination of nitrogen in the Branchville mineral is to be depended on, the rule still holds that the higher the UO_2 the higher likewise is the nitrogen. The Colorado and North Carolina minerals are exceptions, but it should be borne in mind that the former is amorphous like the Bohemian and possesses the further similarity of containing no thoria, though zirconia may take its place, and the North Carolina material is so much altered that its original condition is quite unknown.

In the absence of all positive knowledge as to the rôle which nitrogen plays in the mineral it would be idle to speculate at present upon the proper position of the latter in mineral classification. Much remains to be done before this question can be elucidated.

But two explanations seem possible to account for the wide differences in the oxygen ratios for UO_3 and total bases, varying as they do, from 1 : 4·37 for the Branchville material of analysis VI to 1 : 1 for Blomstrand's Bröggerite and even to a ratio indicating acidity for Nivenite. Either all the others are alteration products of a mineral having the composition of the Branchville occurrence, or even of some unknown body entirely free from UO_3; or they are mixtures of two or more substances. Fractional solution indicates this prettly clearly without decid-

ing between them, for when Glastonbury uraninite was subjected to the action of sulphuric or hydrochloric acids for different periods of time the residue was found to be enriched in UO_2 and likewise in nitrogen, and this enrichment was more or less according as much or little of the mineral had been dissolved.

Whatever may be the eventual conclusion it will be found that the small amount of water afforded by all analyses must be carefully considered. Small as this quantity is, in consequence of its low molecular weight as opposed to uranium, thorium, and lead, it must play an important part in the mineral as a homogeneous whole or in one of its parts if a mixture. In the latter case it will unquestionably be found to belong to the more soluble component.

Attention must be called to one difficulty presented by the analyses for which no satisfactory explanation presents itself. Analysis V was made partly in duplicate with all possible refinements in order to ascertain whether or not the almost constant plus in the summations of those preceding analyses in which all constituents had been determined, or in which it was evident that an excess would result by the estimation of the one or two failing members, was due to impure reagents or to faulty manipulation. The excess still appears, and it seems as if some one of the weighings in all analyses must have been uniformly too high. The cause cannot be sought in a replacement of oxygen by nitrogen in combination with uranium as is often allowable when fluorine is present in a mineral, for since the nitrogen is freed as a gas by sulphuric acid it is immaterial so far as the summation is concerned, whether the proportions of UO_2 and UO_3 as found by titration are correct or not. A certain amount of oxygen has been used, and it does not alter the result whether this has been employed to oxidize a suboxide of uranium to UO_3, supposing nitrogen to have replaced a part of the oxygen in UO_2, or only in oxidizing UO_2 to UO_3. In the former case the actual percentage of UO_3 in the mineral would be increased, but the oxygen consumed would be the same. This matter will be further looked into.

Other very mystifying points have been observed which were revealed in a series of supplementary experiments on Glastonbury uraninite which can here only be outlined in the briefest manner. Experiment having shown that no nitrogen could be obtained by H_2SO_4 or by fusion with an alkaline carbonate after sufficiently long ignition of the mineral in air, it was sought to learn if the final change in weight by such ignition represented the difference between loss of water plus all nitrogen and gain of oxygen from oxidation of UO_2. All experiments made showed a considerable *gain* in weight,

whereas there should have been a large *loss* if the nitrogen had been expelled. No other explanation seems possible than that the nitrogen has entered into some other state of combination from which it is not set free by the usual means. A somewhat similar change seems to result from heating the mineral in hydrogen. All UO_3 is reduced to UO_2 and the usual tests show that the percentage of nitrogen decreases very slowly as the heating is prolonged, but the total loss is by no means equal to the sum of water plus oxygen of UO_3 reduced to UO_2 plus the nitrogen that has disappeared; it is slightly, if any, in excess of water and oxygen from UO_3 alone. Ammonia is not formed. Practically no loss in weight occurs on heating the mineral in CO_2 beyond that representing the water.

Briefly summarized the conclusions are as follows:

First. Nitrogen exists in uraninite in quantities up to over 2·5 per cent, and seems generally to bear a relation to the amount of UO_2 present. This is the first discovery of nitrogen in the primitive crust of the earth.

Second. The condition in which the nitrogen exists is unknown, but it is entirely different from any hitherto observed in the mineral kingdom.

Third. Analysis of uraninite from various localities has shown that, with in general the same constituents, the mineral varies widely in composition, and that its physical characteristics and its behavior toward certain solvents are often as distinct as the chemical differences.

Fourth. The formulæ of Comstock and Blomstrand are inapplicable to the zirconia, thoria, and yttria uraninites of North America and Norway, among which are to be reckoned Bröggerite, Cleveite, and Nivenite, and probably to the varieties free from earths.

Fifth. Extended and most careful examination of uraninite specimens from all possible localities is necessary before any conclusion worthy of acceptance can be reached as to the character of the chemical combination or combinations represented by them. The work in this direction should likewise cover a study of the nitrides and oxynitrides of uranium and thorium, with synthetical experiments aiming at the artificial production of uraninite.

Work will continue in this laboratory as opportunity may offer. It is earnestly to be hoped that those possessing or in a position to secure uraninite specimens will take the trouble to examine them on the lines suggested in the foregoing pages, or if unable to do so, will kindly contribute material for examination here. The interest in the matter is not confined merely to a solution of the composition of this one mineral; it is broader than that, and the question arises, may not nitro-

gen be a constituent of other species in a form hitherto unsuspected and unrecognizable by our ordinary chemical manipulations? And if so, other problems are suggested which it is not now in order to discuss.

Laboratory of the U. S. Geological Survey,
Washington, D. C., June 30th.

ART. L.—*Anthophyllite from Franklin, Macon Co., N. C.;* by S. L. PENFIELD.

As an orthorhombic member of the hornblende group of minerals anthophyllite is of special interest, being a magnesia-iron silicate without calcium, and standing thus in the same relation to hornblende as the orthorhombic enstatite, bronzite and hypersthene do to the monoclinic pyroxene. As far as the author can learn it has never been fully identified from any locality in the United States. Many specimens which may be seen in collections labeled anthophyllite will be found, when examined with the microscope, to be fine fibrous or radiated varieties of hornblende. The material which will be described in the present paper was collected at the dump of the Jenks Corundum Mine, Franklin, Macon Co., N. C., by Mr. Norman Spang, where it is said to occur abundantly, but as it was supposed to be a common mineral only a small specimen was taken away, which he generously gave to the author for determination and investigation.

As anthophyllite is only known from a few localities and as many varieties which have been referred to the species are, according to the analyses, impure or more or less decomposed (indicated by a high percentage of water), a full description of the pure and well crystallized North Carolina mineral seems desirable, especially as the crystals are transparent, rendering it possible to make a fuller determination of the optical properties than has yet been made. The mineral occurs in prismatic crystals, sometimes several centimeters long and nearly 5^{mm} wide in the greatest diameter, imbedded in a green foliated pennine, which latter shows in convergent polarized light under the microscope a uniaxial interference figure with weak positive double refraction. The only forms observed on the anthophyllite are the prism 110, *I* and the brachy-pinacoid 010, *i-i*. No terminations could be found, the crystals when traced to the very end in the pennine becoming irregular and much broken. The prismatic faces have a fine luster but are slightly etched; examined under the microscope they appear to be covered with delicate markings with irregular and mostly

curved contours. They frequently show vertical striations, especially that part of the prism which is nearest to the obtuse angle, and this is frequently rounded off by the oscillatory combination. Nine of the best selected crystals were measured on the reflecting goniometer, but the reflections were somewhat uncertain owing to the striations and surface markings on the prismatic faces. The two best measurements were $I \wedge I$, $110 \wedge \bar{1}10 = 125° 37'$ and $125° 38'$, while the average of fifteen measurements each of

$110 \wedge \bar{1}10$, varying from $125° 25' - 125° 41' = 125° 35'$
$110 \wedge 1\bar{1}0$, varying from $54° 12' - 54° 34' = 54° 25'$

If we take therefore $125° 37'$ as the best measurement, it is very close to the average given above and will certainly very nearly represent the true value. From this the ratio $\breve{a} : \bar{b} = \cdot 51375 : 1$. The above values vary somewhat from the determinations of Des Cloizeaux* on the anthophyllite from Kongsberg in Norway, who gives for $I \wedge I$ about 125°.

The cleavage is very perfect parallel to the prism, 110, and brachy-pinacoid, 010; the latter is easily produced and yields brilliant surfaces although it is always mentioned in the mineralogies as indistinct. The cleavage parallel to the macro-pinacoid, 100, which is always mentioned as perfect was poor and scarcely perceptible.

The crystals are very transparent and have a delicate clove-brown color, the largest ones affording good material for determining the optical properties. The plane of the optical axes is in the brachy-pinacoid, as in all anthophyllites. Two plates were cut, one parallel to the macro-pinacoid, the other parallel to the base. The latter was small and considerable difficulty was experienced in making it at right angles to the good cleavages. From these two plates the divergence of the optical axes was measured on a large axial angle apparatus in the potassium mercuric iodide solution whose indices of refraction were n, red, Li = 1·6650; n, yellow, Na = 1·6811; n, green, Tl = 1·7086 with the following results:

	Macro-pinacoid section.	Basal section.
2 H for red	= 87° 31′	87° 24′
2 H for yellow	= 85 45	88 5
2 H for green	= 83 44	88 28

from which we can calculate:

2 V red	= 90° 4′ $\quad \beta = 1·6276$
2 V yellow	= 88 46 $\quad \beta = 1·6353$
2 V green	= 87 28 $\quad \beta = 1·6495$

* Manuel de Minéralogie, i, p. 75.

We see from the above that the optical axes are about at right angles to one another. There is a marked dispersion about the $\breve{a}$ axis, which is $\rho > \nu$, the brachy axis being the acute bisectrix for green and yellow but obtuse for red. One of the prismatic crystals after polishing the faces served as a prism for determining two of the indices of refraction. The prismatic angle after polishing measured 52° 55′. The minimum deviation for yellow was 41° 0′ for rays vibrating parallel to the vertical axis, and 40° 14′ for rays vibrating parallel to the macro-axis, from which we calculate $\gamma = 1{\cdot}6404$ and $\beta = 1{\cdot}6301$, while β above was found to be 1·6353. From the values of 2V, γ and β for yellow we calculate $\alpha = 1{\cdot}6288$. The optical orientation is therefore $\breve{a} = \mathfrak{a}$, $\bar{b} = \mathfrak{b}$ and $\dot{c} = \mathfrak{c}$. The double refraction is negative for green and yellow, $\breve{a}$ being the acute bisectrix and positive for red, $\dot{c}$ being the acute bisectrix.

Hardness about 6. Specific gravity, by floating in the heavy solution, 3·093.

The purest crystals were selected for analysis by hand-picking which was easily accomplished as the mineral separated readily from the matrix.

The results of analysis on the air-dry powder are as follows:

		Ratio.	
SiO_2	57·98	·966	
FeO	10·39	·144	
MnO	·31	·005	
MgO	28·69	·717	·963
CaO	·20	·004	
H_2O	1·67	·093	
Al_2O_3	·63		
Loss at 100°	·12		
	69·99		

The ratio of $SiO_2 : RO$ (H_2O being included) is ·966 : ·963 or almost exactly 1 : 1, giving the formula $RSiO_3$, R = Mg, Fe, H_2 and traces of Mn and Ca. The mineral when heated in a closed tube over a Bunsen burner was found to be anhydrous and the analysis was made accordingly. After drying the powder at 100° C., the mineral was heated to faint redness in a crucible and lost only 0·19 per cent. On summing up the analysis, which was very carefully made and everything tested, a deficiency of 1·50 per cent was found and moreover the ratio of $SiO_2 : RO = ·966 : ·870$, which indicated a large excess of silica. In trying to account for this deficiency a second sample of the mineral was heated over a blast lamp in a closed glass tube when water was given off in perceptible quantities. The H_2O in the analysis was determined by loss of weight on igniting in a current of CO_2 gas to prevent oxidation. A

second sample was ignited in a closed crucible without CO_2 gas and gave almost the same result, 1·71 per cent. In this sample the FeO was determined, after solution in hydrofluoric and sulphuric acids, and after reduction the total iron. As the mineral after such strong ignition was only slowly acted on by the hydrofluoric acid and in the experiment only partially dissolved, the results were not thoroughly satisfactory but they proved conclusively that the FeO had only been oxidized to a trifling extent and the loss on ignition will represent therefore very nearly the exact percentage of H_2O. That the tendency of FeO, in this combination, to oxidize is not very great is moreover proved by the fact that repeated ignition did not yield any increase in weight. That the H_2O is an essential constituent of the mineral and is not the result of alteration, is proved by the fact that it is very firmly united to the molecule, requiring an intense heat to drive it off, and moreover it is just sufficient to bring the ratio of protoxides to silica = 1 : 1. The transparency of the crystals would moreover prove that the material which was analyzed was very pure and had not suffered any alteration.

Mineralogical Laboratory. Sheffield Scientific School
New Haven, May, 1890.

ART. LI.—*Preglacial Drainage and Recent Geological History of Western Pennsylvania;* by P. MAX FOSHAY, M.S., F.G.S.A.

THE investigation into the preglacial drainage of Western Pennsylvania, of which this paper is a partial record, was primarily incited by a suggestion thrown out by Professor J. W. Spencer, in a paper read before the Am. Phil. Soc., March 18, 1881. Professor Spencer there advanced the hypothesis that the Beaver River, with part of the Ohio, had in preglacial times constituted a stream which flowed up the modern Mahoning through its now buried channel into the Erigan River (Spencer) which then traversed the basin of Lake Erie. This stream, now become parts of several modern rivers, I have named Spencer River in honor of the investigator who first suggested its existence and to whom is due so large a proportion of our present knowledge of the preglacial drainage of the region of the Great Lakes. Spencer River drained an area nearly co-extensive with that of the Pennsylvania portion of the modern Ohio with its tributaries, including the basin of the Monongahela and part of that of the Allegheny, thus

carrying off the rainfall of almost all Western Pennsylvania and Eastern Ohio.

The preglacial drainage of Northwestern Pennsylvania and Western New York was long since thoroughly worked out by Professor John F. Carll, who was the pioneer in this field. In the course of his survey in Northwestern Pennsylvania he collected proof* of the existence of at least two northwardly

flowing preglacial streams which drained the northern part of the present Allegheny basin and debouched, like Spencer River, into the Erigan River. The Allegheny River, as we now know it, did not then exist but was formed after the glacial episode, during which time the mouths of the ancient northwardly flowing streams had been blocked up. This blocking up of the ancient drainage forced the post-glacial

* Report III, Second Geological Survey of Pennsylvania, pp. 330–366. John F. Carll, Harrisburg. 1880.

rivers to overflow to the south and cut down their divides. They united to form the modern Allegheny River and thus we have the phenomenon of reversed drainage in the upper Allegheny region. The story of the Beaver valley is to be told in much the same words, but Professor Carll—not having examined the region—did not see as clearly as Professor Spencer the former drainage of this part of the State. He says,* "I strongly suspect that Big Beaver River is a glacial enlargement of a small ancient stream formed in the same manner as those found in the summit basins and that anterior to the Ice Age the Shenango and other headwater streams of the Beaver, including the Connoquenessing, delivered northwardly through the Mahoning and Grand Rivers into Lake Erie basin. . . . ." If he had placed the ancient divide, cut through during the Glacial Epoch, in the present Ohio valley somewhere between the mouth of the Little Beaver and Wellsburg, W. Va., instead of placing it in the Beaver valley, he would have been correct, as will be seen below.

The evidence that Spencer River, whose bed is now buried beneath many feet of drift materials, once flowed northwardly is to be found in a very complete series of measurements of the depth of the drift filling taken from the records of oil and gas wells drilled in the valleys during recent years. In the table below I give only maximum depths at not too frequent intervals but it must be understood that there is hardly a mile of the distance covered in which there are not one or more records showing the presence of the old channel.

	Dist. from Pittsburgh.	Place.	Low Water. A. T.	Depth of Filling.	Old Floor. A. T.
1.	0·	Pittsburg.	699 ft.	44 ft. †	655 ft.
2.	10·	Coraopolis.	?	50 ft.	?
3.	19·	Aliquippa.	677 ft.	60 ft.	617 ft.
4.	25·2	Beaver.	670 ft.	+60 ft.‡	−610 ft.
5.	29·8	Beaver Falls.	700 ft.	+100 ft.§	−600 ft.
6.	46·8	Lawrence Junc.	760 ft.	+150 ft.‖	−610 ft.
7.	51·4	Edenburg.	780 ft.	200 ft.¶	580 ft.

The figures in the fifth column of the table it will be seen demonstrate a progressive deepening of the drift filling as we go northward and when reduced to tide-level prove that the old floor at present dips slightly to the north.

* Report III, Sec. Geol. Survey Pa., p. 392—footnote.

† An. Rep. Pa. Survey 1886, Pt. II, p. 730. Jones & Laughlin, Nos. 1 and 2.

‡ Rep. Q, Pa. Survey, I. C. White, 1878, p. 14.

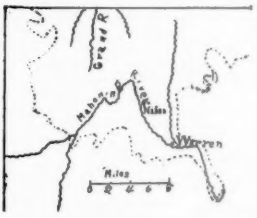
§ Rep. Q, Pa. Survey, I. C. White, 1878, p. 15.

‖ Rep. Q, Pa. Survey, I. C. White, 1878, p. 16, quoted from Dr. J. S. Newberry in Geology of Ohio.

¶ Rep. QQ, Pa. Survey, I. C. White, 1879, pp. 19, 184, 202.

The elevation of No. 6 at the confluence of the Mahoning and Shenango does not constitute an exception as the well from which the record was taken went 150 feet through drift and not having reached rock was abandoned. There is thus a total fall of 75 feet in the 51·4 miles covered by the table, reaching down to an elevation of only eight feet above the present surface of Lake Erie.

The fact of a post-glacial elevation of the northern part of the continent is now well established. The differential uplift shown in the younger beaches about the overlapping ends of Lake Erie and Lake Ontario is about two feet per mile.* Mr. McGee's survey of the rise of the older Columbian drift formation would make the Pleistocene and recent deformation amount to about three feet per mile. Adding this dip to the present profile of the floor of Spencer River we obtain an abundant northward fall of the old bed. Well records at Niles, O., show the presence of the old channel at that point. A few miles north of this point the country falls away towards Lake Erie and a number of country wells give depths of drift filling almost sufficient to *prove* the fall of the old bed far into Grand River basin. In addition to this the Grand River of Ohio, along with the other Ohio Rivers, was shown by Dr. Newberry's survey to have a buried channel amply deep to be a continuation of Spencer River.†



The accompanying figure (fig. 1) shows in dotted line the outcrop of the hard Conglomerate Series as drawn on Orton's geological map of Ohio. The remarkable embayment in this outcrop, heading at Youngstown, O., furnishes strong presumptive evidence of the existence of a reversed drainage in this locality. The Mahoning River after coming into the bay at its side and flowing some miles in the normal direction makes a sudden bend and flows at right angles to its former course *towards* the head of the embayment. The great amount and peculiar form of erosion which the Conglomerate Series has suffered in the formation of this embayment could only have been accomplished by a stream flowing northwardly through the bay in a now deeply buried channel, i. e. Spencer River.

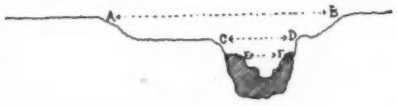
Even disregarding the northward Pleistocene elevation the only other possible outlet for Spencer River is through the

* The Iroquois Beach; by J. W. Spencer. Trans. Roy. Soc. Can., 1889, p. 128.

† Geology of Ohio, vol. ii, p. 199.

valley now occupied by the Ohio below its point of meeting with the Beaver. That this could not have been the outlet is proved by the following facts:—at Smith's Ferry, on the Pennsylvania Ohio State line, two favorably situated measurements give a maximum depth of drift filling of 30 feet* and at Steubenville, O., the channel could not possibly have been deep enough to drain Spencer River.† The conclusion is thus made imperative, independent of the northward crust movements, that this area must have drained northwardly into the Erie basin. This ancient basin would then include the areas now drained by the Lower Allegheny, Clarion, Redbank, Mahoning, Conemaugh, Youghiogheny, Cheat, Monongahela and Little Beaver Rivers. The Monongahela and Allegheny are both known to have buried valleys, the former‡ as far as its junction with the Youghiogheny and the latter§ to somewhere north of Parker.

The topography of the Beaver Valley is shown in fig. 2, which is an ideal cross-section. It consists first of an old base-level plain (AB) bounded on either side by slopes rising slowly to the level of the table-land which is the basis of the topography of the region; of a rock gorge (CD) extending from 300 to 350 feet below the level of the plain, which is completely filled with drift for the lower 100 feet and partially for the next 125 feet; and of an inner gorge (EF) in the drift whose excavation by the modern river gave us the drift terrace system.



AB, old base-level plain.
CD, outer or rock gorge.
EF, inner or drift gorge.
The shaded portion represents the drift filling of the old rock gorge with its terraces of erosion.

The old base-level plain has more frequently been called the "fourth terrace," though it was known to have no connection with the other terraces. It is a mile or more in width and is covered in all places south of the terminal moraine by a deposit consisting of white or yellowish clay, of variable thickness up to ten feet, which in places contains intermingled pebbles of northern drift, and frequently has sand or gravel above or below it, or both. The maximum observed thickness of the whole deposit is twenty feet. This clay deposit is very constant wherever the old base-level plain—a mere bench often—is found. The plain has in all places, south of the moraine, a rocky scarp on its river side and is always (in the Ohio and

* Report QQ, I. C. White, Sec. Geol. Survey Pa., 1879, p. 16.
† Report QQ, I. C. White, Sec. Geol. Survey Pa., 1879, p. 17.
‡ Report K, Sec. Geol. Survey Pa., J. J. Stevenson, 1876, p. 20.
§ Report V, Sec. Geol. Survey Pa., H. M. Chance, 1879, ix, x and 19.

lower Beaver valleys) at a higher elevation than any of the Pleistocene terraces. It is most marked in the Beaver valley on account of its being formed for the most part from the more resisting rocks of the Conglomerate Series, but it is easily made out in the Ohio valley from Pittsburg to Beaver and also far up the Allegheny and Monongahela valleys. South of Beaver, on the Ohio, it has not been observed. Ascending the Beaver the plain falls from 915 feet A. T. at Beaver Falls to 890 feet A. T. at the mouth of the Connoquenessing—a distance of ten miles. There can be no doubt that this was once the bed of an ancient river at a time long anterior to the First Glacial epoch, and, from its northward fall, the stream must have flowed in that direction. The plain thus indicates a long epoch, when the preglacial drainage had not yet cut the deep cañons which marked the topography of the later Tertiary period. The clayey deposit over the plain belongs to a Pleistocene epoch antedating that during which the terminal moraine was formed as it seems to pass beneath the moraine with its kames at the point of contact. It seems to record an episode when the continent was lower than now. Possibly it may be contemporaneous with McGee's Columbia formation (?)

Following the period of the base-level plain came long ages of high continental elevation—higher than the present—during which all the streams of Western Pennsylvania cut channels far below their present beds. This epoch (Pliocene ?) was either one of slight precipitation or of comparatively short duration as none of the tributary streams reached a base-level of erosion but were flowing through V-shaped cañons of rather rapid fall when the period of the terminal moraine with its subsidence filled all these old channels with drift to nearly the level of the old base-level plain. During all the foregoing time Spencer River had drained the region in question, its waters delivering into the Erie basin. After the deposit of the drift in the valleys of Pennsylvania a divide was formed across the old channel of Spencer River at Orwell, O., and the drainage of the region became for the most part reversed—the waters now finding their way into the lower Ohio and thence to the Mississippi.

The northern elevation of the continent so thoroughly worked out by Gilbert and Spencer in New York and Ontario occurred at this same time and so confirmed the region in its drainage to the south. The modern rivers now began eroding their beds of drift and are still at work. That this process has gone on uninterruptedly for a long period of time is shown by the fact that many of the tributaries of the Beaver and Ohio have flat flood plains, underlaid by the buried channels of the former drainage level, extending two miles or more back from

the river. There is every indication however of a very modern elevation (40± feet) of the region, accompanied by a rapid deepening of the main channels of drainage, in the fact that these tributaries have but recently begun eroding their beds near their mouths. This process has in no case extended more than one-fourth mile. In thus eroding their beds the streams in many cases have deepened their channels in lines which do not correspond with their buried channels but lie to one side or the other; and so we find them running over ledges of rock near their mouths, which has led many observers to the conclusion that the tributaries could not flow over buried channels. In all cases that I have examined, however, I have found strong evidence of the existence of such channels—of which there is positive proof in many wells and excavations.

Beaver Falls, Pa., August 9, 1890.

ART. LII.—*On the so-called Perofskite from Magnet Cove, Arkansas;* by F. W. MAR.

IN 1877, it was shown by Knop,* that the supposed perofskite of the Kaiserstuhl, contained besides titanium a considerable amount (23 p. c.) of niobium and tantalum, and he accordingly made it an independent species and named it very appropriately *Dysanalyte.* The analysis of the similar mineral from Magnet Cove, Arkansas, the results of which are given below, shows that it is also distinct from perofskite and is to be classed with dysanalyte. For the material for analysis I am indebted to the kindness of Professor E. S. Dana.

The method of analysis was as follows: 0·500 gram. of the carefully selected mineral were placed with about 15cm³ of concentrated sulphuric acid in a platinum crucible of 150cm³ capacity and, the whole being covered with a watch-glass that the progress of the decomposition might be easily observed, boiled for ten or fifteen minutes. The cooled product was poured into 600 or 700 cm³ of cold water and allowed to stand over night or until the calcium sulphate was completely dissolved. A small residue was usually found and this was put through the same process. Any final residue is silica and sometimes a little tantalum or niobium oxide. The former was determined by evaporation with sulphuric and hydrofluoric acids and the remaining oxide was added to the main oxides.

* Zeitschr. für Kryst., i, 284, 1877.

The solution of the mineral was then made slightly alkaline with ammonia and the precipitated earth filtered off. The lime was thrown out of the concentrated filtrate as oxalate and after evaporation and volatilization of ammonia salts, magnesia was determined in the residue. Alkalies should be found at this point if present. There were none.

The weighed earths obtained as above were fused in sodium carbonate, enough sulphuric acid added to the mass to bring about a bisulphate fusion and then enough more to keep the whole in the liquid condition even when cold. After cooling, the mass was poured into 300 cm^3 of cold water containing 1 grm. of tartaric acid and after separating the iron, in alkaline solution, by hydric sulphide, the titanium, with which go the niobium and tantalum, were separated by the acetic acid process of Professor Gooch.* The greater part of the manganese was separated by an ordinary acetate process and the acid oxides by the strong acetate process. On neutralizing the filtrate from this last with ammonia and boiling, only a trace of some earth was found, showing absence of alumina. The titanium was separated from the weighed oxides by Knop's chlorinating process, and finally the niobium was determined in the mixture of niobium and tantalum oxides by reduction in hydrochloric acid and titration with permanganate after T. B. Osborne.† Only a trace of titanium was found in the niobium and tantalum oxides by the Osborne process with hydrogen peroxides, and the titanium re-estimated by the same process gave practically the same result as before.

A portion of the oxides having been lost during the operation, having gone, as it appeared, with the manganese used to decompose the tartaric acid, another portion of mineral was treated in the same manner as far as this point, and the tartaric acid was destroyed by evaporation in platinum and ignition. No aluminum having been found, the titanium, tantalum and niobium oxides were separated by boiling with dilute sulphuric acid. By evaporation of this filtrate a quantity of earths was obtained. To this was added another portion separated by ammonia from the filtrate (in the same portion of mineral) after separation of lime, evaporation and ignition and solution in hydrochloric acid, and before the precipitation of the magnesia by microcosmic salt. The combined earths were precipitated in a slightly acid solution by oxalic acid in order to separate from any uranium, the cerium and yttrium groups separated by the sodium sulphate process and each precipitated again as oxalate and weighed as oxide. As appears the main portion of the rarer earths belongs to the yttrium group.

* Proceedings Amer. Acad. of Arts and Sci., N. S., vol. xii, p. 435.

† This Journal, vol. xxx, p. 329.

An attempt was made to take the atomic weight, but the result obtained, 190, is probably too high, the color showing that part of the sulphate was changed to a basic salt. This, however, with the color of the oxides, a reddish-brown, and the fact that the solutions do not yield an absorption spectrum, suggests that a chief portion of the earth is terbium oxide.

The result of the analysis is as follows:

Specific gravity = 4·18.

				Molec. Ratio.		Quantiv. Ratio.	
CaO	33·22	÷	56 = ·593	·611 or 23 × 2	1·22		=4
MgO	0·74	÷	40 = ·018				
FeO	0·23	Fe_3O_4					1·52 or 3
	0·50						
Fe_2O_3	5·66	÷	160 = ·035				
$[Yt, Er, Tr]_2O_3$	5·42	÷	428 = ·012	·050 or 2 × 6	·300		=1
$[Ce, La, Di]_2O_3$	0·10	÷	328 = ·003				
Nb_2O_5	4·38	÷	268 = ·016				=1
Ta_2O_5	5·08	÷	444 = ·011	·027 or 1 × 10	·270		2·43 or 5
TiO_2	44·12	÷	82 = ·538				=7
SiO_2	0·08	÷	60 = ·001	·539 or 20 × 4	2·156		
	99·53						

In conclusion I would express my thanks to Professor Gooch of the Kent Laboratory for the valuable advice and assistance freely given by him during the course of the analysis.

Kent Laboratory, Yale University, July, 1890.

ART. LIII.—*Experiments upon the Constitution of the Natural Silicates;* by F. W. CLARKE and E. A. SCHNEIDER.

[Continued from p. 312.]

4. *The Chlorite group.*

In this interesting but very obscure group of minerals, three species were examined. First, the dark-green, broadly foliated, mica-like ripidolite from Westchester, Pennsylvania. This mineral has been repeatedly analyzed, and our results confirm the older data. Second, a dark-green, scaly-granular prochlorite, found in excavating the water-works tunnel in Washington, D. C. Third, leuchtenbergite from the Schischimsk mine near Slatoust, Siberia. The last mineral was kindly sent us by Mr. A. Lösch of St. Petersburg; but it unfortunately contained inclusions which render our work upon it of little value. The prochlorite was examined microscopically by Mr. Lindgren of the U. S. Geological Survey, who found it to be quite homogeneous. Analyses as follows:

	Ripidolite.	Prochlorite.	Leuchtenbergite.
SiO_2	29·87	25·40	32·27
Al_2O_3	14·48	22·80	16·05
Cr_2O_3	1·56	----	----
Fe_2O_3	5·52	2·86	4·26
FeO	1·93	17·77	·28
NiO	·17	----	----
MnO	----	·25	----
MgO	33·06	19·09	29·75
CaO	----	----	6·21
H_2O	13·60	12·21	11·47
F	----	trace	----
	100·19	100·38	100·29
H_2O at 105°	----	·80	·38
" 250°–300°	·95	·15	·21
" 383°–412°	·49	·62	----
" 498°–527°	----	·09	----
" red-heat	11·74	10·55	10·69
" white-heat	·42	----	·19

Here again we have to deal with water which is plainly constitutional. Hence the suggestion put forward by one of us that the chlorites are essentially micas plus water of crystallization, must be abandoned.*

Upon treatment with dry hydrochloric acid gas at 383°–412°, the three minerals differ considerably. The times of heating and the bases converted into chlorides were as follows:

	Ripidolite.	Prochlorite.	Leuchtenbergite.
Hours heated	19	31	34
MgO removed	13·46	1·54	6·29
R_2O_3 removed	4·24	2·17	·42
SiO_2 removed.....	·92	----	----

In a second experiment with the ripidolite 58 hours of heating were required before constant weight was attained, and 13·36 per cent of magnesia plus 1·20 of sesquioxides were rendered soluble. In a third experiment the heating lasted 30 hours, and the percentages of MgO and R_2O_3 removed were 11·10 and 3·31 respectively. Even at the ordinary temperature of the laboratory ripidolite was decidedly attacked by the gaseous acid, 4·66 MgO and 3·43 R_2O_3 becoming soluble. In this case the experiment lasted 100 hours. In the case of the prochlorite the result obtained is of very doubtful significance. In a mineral containing so large a proportion of ferrous iron, secondary reactions due to oxidation are possi-

* Clarke, "A theory of the mica group," this Journal, Nov., 1889.

ble, and it is not practicable to determine exactly what changes have taken place The group —Fe—OH might behave like MgOH, and yet subsequent alteration might prevent any estimate of the extent of the reaction.

By digestion with strong, aqueous hydrochloric acid, both ripidolite and prochlorite were completely decomposed. Leuchtenbergite, on the other hand, left an insoluble residue, resembling garnet, which was originally present as an inclusion in the mineral. All of these minerals decompose with aqueous acid more slowly than the serpentines.

By sharp ignition, ripidolite and prochlorite give up in the free state small quantities of silica, which are determinable by extraction with soda solution. The percentages were as follows:

	Ripidolite.	Prochlorite.
SiO_2 liberated	2·98	2·45

These quantities represent only one-tenth of the total silica in the minerals, and have no evident significance in a discussion of the chemical structure.

Although ripidolite is readily decomposable by aqueous hydrochloric acid, it appears to be split up by prolonged ignition into a soluble and an insoluble part. A weighed quantity of the mineral was heated for nine hours over the blast-lamp, and then digested for three days with hydrochloric acid of sp. gr. 1·12. The residue amounted to 48·47 per cent of insoluble matter, from which boiling with sodium carbonate solution extracted 28·73 of silica belonging to the decomposed silicates. The final undissolved residue, 19·74 per cent, was analyzed; and, treated as an independent substance, gave as follows:

SiO_2	6·32
Sesquioxides	67·81
MgO	25·67
	99·80

If the small quantity of silica here found, only 1·25 per cent of the original material, be neglected as non-essential, the remainder, 18·49 per cent of the ripidolite, has exactly the composition of spinel. Like spinel it is quite insoluble, and in all reasonable probability it may be regarded as that compound. The formation of such a magnesian aluminate, $MgAl_2O_4$, is peculiarly suggestive when we come to consider the structure of the chlorites.

Similar experiments with the prochlorite gave similar but not identical results. After long ignition, six hours, and three days' digestion with hydrochloric acid, 35·61 per cent of residue remained, of which 18·16 per cent was insoluble in carbonate

of soda. This last residue, however, was rich in silica, and therefore could not be spinel. The reaction deserves further study; but the oxidizability of the iron in prochlorite introduces elements of uncertainty which would render it very difficult to interpret the results.

In the case of the leuchtenbergite, little else was done. By means of Thoulet's solution 5·62 per cent of a yellowish garnet were separated from the mineral, which accounts for part, but not all, of the lime found in the analysis. On this species our results are of little value, except as regards the character of the water which it contains, and its comparative behavior towards gaseous HCl.

Now, in order to discuss the formulæ of the three chlorites, we may reject as adventitious the small quantities of water given up at or below 300°. This leaves as essential water in ripidolite, prochlorite, and leuchtenbergite, 12·65, 11·26, and 10·88 per cent respectively. Using these figures for water the analyses give the following molecular ratios.

	Ripidolite.	Prochlorite.	Leuchtenbergite.
SiO_2	·498	·423	·538
R_2O_3	·186	·241	·185
RO	·855	·727	·858
H_2O	·703	·626	·604

Hence we have the following empirical formulæ:

Ripidolite	$19R_2O_3$, $86RO$, $70H_2O$, $50SiO_2$
Prochlorite	$24R_2O_3$, $73RO$, $63H_2O$, $43SiO_2$
Leuchtenbergite	$19R_2O_3$, $86RO$, $66H_2O$, $54SiO_2$

And these, reduced to an orthosilicate basis become

Ripidolite	$R'''_{38}R''_{86}H_{140}(SiO_4)_{50}O_{113}$
Prochlorite	$R'''_{48}R''_{73}H_{126}(SiO_4)_{42}O_{128}$
Leuchtenbergite	$R'''_{38}R''_{86}H_{120}(SiO_4)_{54}O_{95}$

This excess of oxygen over the orthosilicate ratio can only be interpreted as basic hydroxyl; whence we get

Ripidolite	$R'''_{38}R''_{86}H_{27}(SiO_4)_{50}(OH)_{113}$
Prochlorite	$R'''_{48}R''_{73}(SiO_4)_{42}(OH)_{127}$
Leuchtenbergite	$R'''_{38}R''_{86}H_{25}(SiO_4)_{54}(OH)_{95}$

The last of these formulæ is vitiated by the fact that the mineral analyzed was impure; a fact which appears in the low figure for the hydroxyl, which garnet does not contain. Otherwise it is clear that in general leuchtenbergite and ripidolite agree quite nearly with each other. The question now to be answered is, how shall the hydroxyl be apportioned between the bases?

Taking ripidolite as the mineral of the three which has been most completely examined, we may recall that two concordant experiments with gaseous hydrochloric acid gave 13·36 and 13·46 per cent of removable magnesia, presumably representing the group MgOH. In mean, these percentages correspond to 34 atoms of magnesia. Regarding this as an index of the MgOH present, we may combine the remainder of the hydroxyl with the sesquioxides to form the univalent group AlH_2O_2, and the ripidolite formula now becomes $(AlH_2O_2)_{38}(MgOH)_{34}R''_{52}H_{27}(SiO_4)_{50}$; with three oxygen atoms unaccounted for and negligible. Generalizing this expression we have

$$R''_{52}R'_{99}(SiO_4)_{50}.$$

or almost exactly, $R''_2(SiO_4)_2R'_4.$

This is an olivine formula, with half of the R″ replaced by R'_2, and is strictly comparable with the formula of serpentine. It will be remembered that von Wartha* some time ago advanced the opinion that the chlorites and serpentines form one continuous series of minerals, and his view is by this discussion curiously supported. Furthermore, the probable juxtaposition of the groups AlH_2O_2 and MgOH in ripidolite accounts in great measure for the apparent formation of spinel when the mineral is decomposed by heat.

The ratios found by analysis between H, MgOH, and AlO_2H_2, indicate that ripidolite is probably a mixture of two isomorphous molecules; and the observed data are best satisfied by assuming the compounds $Mg_2(SiO_4)_2(MgOH)_2H$ and $Mg_2(SiO_4)_2(AlO_2H_2)_2H$ in equal proportions. For a mixture of these molecules in the ratio of 1 : 1, the composition is easily calculated; and the results agree well with the analysis. If, in the latter, we recalculate the ferric and chromic oxides to their equivalent in alumina, and compute the ferrous oxide as magnesia, reducing the summation afterwards to 100 per cent, we get the following direct comparison between analysis and theory:

	Found.	Theory.
SiO_2	31·18	31·09
Al_2O_3	19·87	19·82
MgO	35·74	36·27
H_2O	13·21	12·82
	100·00	100·00

A closer concordance could hardly be expected.

For prochlorite, notwithstanding the uncertainty as to the behavior of the ferrous iron, similar ratios appear. The ex-

* Groth's Zeitschrift, xiii, p. 71, 1887.

pression $R'''_{48}R''_{73}(SiO_4)_{42}(OH)_{127}$ reduces to $(AlH_2O_2)_{48}(R''OH)_{31}R''_{42}(SiO_4)_{42}$; in which R″OH is mainly Fe″OH and R″ is almost entirely Mg. This, generalized, becomes $R''_{42}(SiO_4)_{42}R'_{79}$, which is quite nearly the olivine-serpentine type of formula. A mixture of such molecules in which R′ is satisfied by MgOH, FeOH, and AlH_2O_2 in the ratio of 1:3:6; would have the subjoined composition; which is comparable directly with the results of analysis.

	Found.	Calculated.
SiO_2	25·40	24·88
Al_2O_3	22·80	25·37
Fe_2O_3	2·86	
FeO	17·77	17·91
MgO	19·09	19·90
H_2O, essential	11·26	11·94
	99·18	100·00

If the first column were recalculated to 100 per cent, with the ferric iron reduced to its equivalent in aluminum, the agreement would be even closer. In brief, prochlorite seems to have a constitution strictly analogous to that of ripidolite; although, on account of its high proportion of ferrous iron it behaves differently towards gaseous hydrochloric acid. The leuchtenbergite evidently has a similar structure; but the impurities in the sample analyzed preclude us from discussing this species more in detail. Just as the micas are derived by substitution from normal aluminum salts, so the chlorites are derived from normal magnesium silicates; and, in a very curious way the two series seem to approach each other. Thus a compound having the chloritic formula $Mg_2(SiO_4)_2(AlO_2H_2)H_2$, if halved, may be written as if it were a derivative of aluminum orthosilicate analogous to some of the more basic hydromicas; and the close physical similarity between the two groups is thus remarkably emphasized.

5. *The micas.*

In this group only three examples were studied, all of the magnesian or ferro-magnesian class. A. Phlogopite from Burgess, Ontario. The ordinary, slightly brownish, broadly foliated mica, somewhat resembling muscovite. B. Phlogopite from Edwards, St. Lawrence County, New York. The peculiar, non-fluoriferous variety, superficially resembling brucite, described by Penfield and Sperry; whose analysis is thoroughly confirmed by ours. C. A nearly black, broadly-foliated iron mica from Port Henry, New York. Commonly regarded as a lepidomelane. Analyses as follows:

	Burgess.	Edwards.	Port Henry.
SiO_2	39·66	45·05	34·52
TiO_2	·56	----	2·70
Al_2O_3	17·00	11·25	13·22
Fe_2O_3	·27	----	7·80
FeO	·20	·14	22·27
MnO	----	----	·41
(Co,Ni)O	----	----	·30
CaO	none	----	----
BaO	·62	----	----
MgO	26·49	29·38	5·82
Li_2O	----	·07	·04
Na_2O	·60	·45	·16
K_2O	9·97	8·52	8·59
H_2O	2·99	5·37	4·39
F	2·24	----	·34
P_2O_5	trace	----	trace
	100·60	100·23	100·54
Less O	·94		·14
	99·66		100·40

The fractional water determinations gave—

	Burgess.	Edwards.	Port Henry.
H_2O at 105°	·66	----	·57
" 250°–300°	·35	·73	·45
" red-heat	1·98	·73	3·37
" white-heat		3·91	

In all the analyses of this investigation, when much iron was found, the total water was determined directly; so that the figures for the higher temperatures do not represent mere loss on ignition. In these micas the percentages of constitutional water, to be used in the discussion of formulæ, are 1·98, 4·64, and 3·37 respectively.

In the Burgess phlogopite numerous inclusions were observed, consisting of slender prisms, and at our request these were examined microscopically by Mr. Waldemar Lindgren. The mica, according to his examination, is made up of "thin foliæ, under the microscope colorless, dark between crossed nicols; interference figure apparently a cross, not separating into hyperbolas; seemingly uniaxial, but with better instruments it would probably be found to be biaxial with a very small axial angle. Shows excellent asterism, caused by interpositions arranged in three directions cutting each other at an angle of 60°. The inclusions are prisms of a strongly refracting and bi-refracting mineral, so thin as to show brilliant Newton's colors. In spite of the very small thickness, the

interference colors are near the white of the first order. Extinction takes place strictly parallel to the prismatic surface. Terminal faces rounded, or unequally developed. Beside prisms there are square or rhomboidal foliæ, probably of the same substance. The inclusions were first observed by G. Rose (Neues Jahrbuch, 1863, p. 91) who regarded them as kyanite. Rosenbusch describes them again, and determines them as tourmaline (Physiog. der Mineralien, p. 486). The prisms certainly correspond well in their optical characteristics to this mineral. Kyanite and apatite are excluded from among the possibilities. Probably, in spite of its apparent abundance the mineral is but a very small fraction of the mica substance. At Mr. Lindgren's suggestion the mica was carefully tested for boron, but none was found. Hence tourmaline, if present, must be in exceedingly small quantities.

On account of the high proportion of titanium in the Port Henry iron mica, this too was examined by Mr. Lindgren, who reports as follows: "It is a dark-brown, unusually deep colored, apparently uniaxial biotite, without inclusions, and especially, as far as examined, free from any titanium mineral." Hence the titanium is to be regarded as a constituent of the mica itself.

The action of gaseous hydrochloric acid upon these micas, at 383°–412°, was almost insignificant. The data are subjoined.

	Burgess.	Edwards.	Port Henry.
Hours heated	12	20	33
MgO removed	·40	1·00	trace
R_2O_3 "	none	·21	·44
SiO_2 "	....	·13	....

In the case of the Port Henry mica some iron was volatilized as chloride. This was estimated; and it was found that the total iron taken out, reckoned as FeO, amounted to only 1·62 per cent. An experiment on the Edwards phlogopite at 498°–527°, lasting 18 hours, gave 1·41 per cent of removable magnesia. This quantity has a possible bearing upon the formula of the mineral.

By aqueous hydrochloric acid all three of the micas were completely decomposed. Hence the Burgess phlogopite could have contained little tourmaline, for that mineral is not soluble in the acid. Moreover, the solubility of the micas prevents us from assuming in either of them an admixture of a muscovite molecule, for muscovite also is insoluble. A careful comparison of the two phlogopites showed that the fluoriferous variety was much more stable towards acids than the rarer non-fluoriferous mineral; a fact which also appears in the action of the gaseous acid upon them. When the two varieties

are treated side by side with hydrochloric acid, the Edwards phlogopite decomposes much more rapidly than the Burgess mica.

After very prolonged ignition the Edwards phlogopite and the Port Henry iron mica were still completely decomposable by aqueous hydrochloric acid. There was, therefore, no splitting up of their molecules which could be determined by this method. The Burgess phlogopite, on the other hand, showed a small amount of change. After eight hours of ignition over the blast, treatment with strong hydrochloric acid for three days, and subsequent leaching with soda solution to remove free silica, 2·45 per cent of insoluble residue remained. This, analyzed, gave

SiO_2	30·94
R_2O_3	48·06
MgO	19·01
Alkalies	undet.
	98·01

This agrees quite nearly with the formula $MgAl_2SiO_6$, which is the composition of a possible member of the clintonite group.

Now from the analyses of the micas we get the subjoined molecular ratios; in which titanic oxide is thrown in with the silica, the alkalies are united as potash, and only the essential water, stable above 300°, is retained.

	Burgess.	Edwards.	Port Henry.
SiO_2	·668	·751	·609
R_2O_3	·169	·110	·177
RO	·669	·736	·464
K_2O	·116	·098	·094
H_2O	·110	·258	·187
F	·118	----	·018

Hence we have the following empirical formulæ:

Burgess ..... $17R_2O_3 . 67RO . 12K_2O . 11H_2O . 67SiO_2 . 12F.$
Edwards ..... $11R_2O_3 . 74RO . 10K_2O . 26H_2O . 75SiO_2.$
Port Henry... $18R_2O_3 . 46RO . 9K_2O . 19H_2O . 61SiO_2 . 2F.$

Deducting oxygen equivalent to the fluorine we have—

Burgess ..... $R'''_{34}R''_{67}K_{24}H_{22}Si_{67}O_{269}F_{12}.$
Edwards ..... $R'''_{22}R''_{74}K_{20}H_{52}Si_{75}O_{293}.$
Port Henry..... $R'''_{36}R''_{46}K_{18}H_{38}Si_{61}O_{249}F_2.$

In all of these micas the silicon and oxygen are present in almost the exact orthosilicate ratio; but in order to discuss the expressions further it is necessary to recall the theory of the mica group which has already been cited. Upon that theory,

all these salts should be substitution derivatives of normal aluminum orthosilicate, from which the more definite micas develop as follows:

Normal orthosilicate	$Al_4(SiO_4)_3$.
Muscovite	$Al_3(SiO_4)_3KH_2$.
Normal biotite	$Al_2(SiO_4)_3Mg_2R'_2$.
Normal phlogopite	$Al(SiO_4)_3Mg_3R'_3$.

Applying these formulæ to the expression given above for the Burgess phlogopite, and regarding the fluorine as present in a group —Mg—F, we have for the composition of that mineral:

$$Al(SiO_4)_3Mg_3KH_2 + Al_2(SiO_4)_3Mg_2K(MgF),$$

the two molecules being mixed in the ratio 1 : 1. Recalculating the original analysis to 100 per cent, uniting TiO_2 with SiO_2, Fe_2O_3 with Al_2O_3, FeO and BaO with MgO, and Na_2O with K_2O, we have this comparison:

	Found.	Calculated.
SiO_2	41·04	41·09
Al_2O_3	17·59	17·46
MgO	27·39	27·39
K_2O	10·62	10·73
H_2O	2·03	2·07
F	2·29	2·17
	100·96	100·91
Less oxygen	·96	·91
	100·00	100·00

The results for the non-fluoriferous phlogopite from Edwards are less satisfactory. Its formula, condensed a little from that given above, is

$$R'''_{22}R''_{74}R'_{12}Si_{76}O_{293},$$

in which the ratio between R''' and Si is 1 : 3·5 nearly. But in this mica, three atoms of magnesia are removable by gaseous HCl, corresponding to 3MgOH. If we assume that this represents a small admixture of a foliated serpentine, and deduct proportionally, there remains

$$Al_{22}Mg_{65}H_{40}K_{20}Si_{69}O_{266},$$

which is very nearly $Al(SiO_4)_3Mg_2KH_2$, or normal phlogopite. At first, as the mineral occurs in a talc mine, we suspected that its anomalies might be due to intermingled talc; but its complete decomposability by hydrochloric acid showed that supposition to be incorrect. If the mica theory is correct, this

mineral must contain a small amount of impurity; and a serpentinous or chloritic molecule is the most probable admixture.

In the Port Henry mica the ratios are perfectly simple. The formula, $R'''_{36}R''_{46}K_{18}H_{38}(SiO_4)_{61}O_5F_2$, if we neglect the small amounts of fluorine and excessive oxygen, reduces easily to a mixture of the three typical molecules:

$$Al_2(SiO_4)_3Fe''_2KH,$$
$$Fe'''_2(SiO_4)_3Fe''_2KH,$$
$$Al(SiO_4)_3Mg_2KH_2,$$

in the ratio 2:1:1. This compares well with the analysis, reduced as usual, thus:

	Found.	Calculated.
SiO	37·02	37·41
Al_2O_3	13·39	13·34
Fe_2O_3	7·90	8·34
FeO	22·56	22·51
MgO	6·30	6·26
K_2O	9·08	9·79
H_2O	3·75	2·35
	100·00	100·00

Here the theoretical water is too low and the potash too high; both outside the allowable range of error. Their reciprocal replacements explain the slight discordance only in part; and the nature of the mineral suggests a small excess of water due to incipient alteration. Altogether the agreement between analysis and theory is remarkably close.

[To be continued.]

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On an improved Vapor-density Method.*—The method proposed by Schall for determining vapor-density depends upon a comparison of the pressure exerted by a certain known amount of gas let into the bulb and measured under normal conditions, with that exerted by the vapor of the substance itself produced by heating this bulb. Originally a measured volume of air was passed into the bulb; but he has now improved the method by decomposing a weighed quantity of pure sodium carbonate within the apparatus, and then comparing the pressure of the carbon dioxide evolved with that of the vaporized substance. The apparatus consists of a long-necked flask, of 150 to 200cm³. capacity, having a lateral tube near its mouth. This flask is supported within a beaker containing the heating material, by a cork surrounding its neck and resting upon a plate of asbestos, serving as a cover. The lateral tube, which should be 10cm. above the bulb, is con-

nected first to a T tube, and by means of this to a vertical manometer tube 73cm. long and 4 or 5mm. in diameter standing in mercury. The vertical portion of the T tube is attached, by a rubber tube furnished with a pinch-cock, to the evolution tube. This tube is about 12mm. wide for a distance of 5 or 6cm. at its lower end, and is drawn out at the upper to enter the rubber tube. Its lower end is closed by a rubber cork. The neck of the flask is closed above by a rubber tube and a pinch cock, this tube being large enough to contain the glass tube in which the substance to be examined is placed. In making an experiment, the beaker, standing on a metal plate and surrounded with the upper half of a somewhat larger beaker serving to prevent cooling by the external air, is heated until the vapor of the heating material—diphenylamine, for example—fills about two-thirds of its volume. By exhausting the air through the rubber tube attached to the vertical part of the T, the mercury is raised to a considerable height in the manometer tube, the pinch-cock being then closed. If the apparatus is tight, this height will remain constant. The evolution tube, in which has been placed the sodium carbonate contained in a small weighing tube, and also the sulphuric acid necessary to decompose it, is then attached to this rubber tube, the pinch-cock is opened and the height of the mercury in the manometer tube is marked by means of a rubber ring. By inclining the evolution tube the acid comes in contact with the carbonate and evolves carbon dioxide, which depresses the mercury column to a point marked with a second ring. The pinch-cock above the flask is now opened and the substance allowed to fall into the latter. Its vapor produces a still further depression of the mercury, its level being marked with a third ring. Calling the position of the first ring k_6, that of the second k_5, and that of the third k_4, and taking the specific gravity of carbon dioxide to be 1·529, the expression for the vapor-density D becomes

$$D=\frac{s}{s'}\times 3{\cdot}682\times\frac{k_6-k_5}{k_5-k_4}$$

in which s and s' represent the mass of the substance and of the carbon dioxide respectively, and $\frac{k_6-k_5}{k_5-k_4}$ the pressure-ratio of the carbon dioxide to the vapor. If s be made equal to s' so that the mass of the sodium carbonate employed is equal to that of the substance, then the simpler expression $D=3{\cdot}682\times\frac{k_6-k_5}{k_5-k_4}$ may be used, it being necessary only to determine the pressure-ratio of the vapor to that of the carbon dioxide evolved from the same weight of sodium carbonate. Vapor-densities of benzoic acid, napthalene, phenol, aniline, nitrobenzene and benzene determined in this way are given which are quite satisfactory.—*Ber. Berl. Chem. Ges.*, xxiii, 919, Apr., 1890; *J. Chem. Soc.*, lviii, 681, July, 1890. G. F. B.

2. *On an improved form of Grove's Gas Battery.*—MOND and LANGER have experimented with the gas battery of Grove with a view of utilizing it commercially. In its improved form it consists of a flat porous diaphragm of non-conducting material having transverse metallic strips let in to its surface at intervals, and covered on both sides with thin platinum foil having 1,500 or more perforations per square centimeter, this foil being covered with platinum black. Several such diaphragms are placed together, with non-conducting frames intervening so as to form chambers, and immersed in dilute sulphuric acid. A current of air is passed through one set of these chambers and a current of hydrogen through the other set alternate with these, so that one side of each diaphragm is exposed to one gas only. The best platinum black for this purpose was obtained by reducing a boiling alkaline solution of platinic chloride with sodium formate; an electromotive force of 0·97 volt being thus obtained. In practice it was found preferable to work the battery at 0·73 volt; in which case a battery having 700 sq. cm. of active surface, covered with 0·35 gram of platinum foil and one gram of platinum black gives a current of 2 to 2·5 amperes. It was observed that no less than half the energy of combustion of the hydrogen is obtained as electrical energy. No material advantage results from the use of pure oxygen and hydrogen over that of air and water gas, the latter obtained by passing steam over red hot coke. The temperature should be maintained constant at 40° by regulating the supply of air.—*Proc. Roy. Soc.*, xlvi, 296; *J. Chem. Soc.*, lviii, 841, Aug., 1890. G. F. B.

3. *On the formation of Hydrogen Peroxide from Ether.*—DUNSTAN and DYMOND have studied the conditions under which hydrogen peroxide is formed from ether. They find that contrary to the received opinion, no hydrogen peroxide is formed when properly purified ether is exposed to light under ordinary atmospheric conditions, either in contact with air or water; the results recorded by former observers having been due apparently to the use of impure ether When prepared by the action of sodium ethoxide in excess on ethyl iodide, and exposed to full daylight for five months and to the electric light for two months for three hours nightly, the ether showed no reaction with potassium iodide, hydriodic acid or chromic acid. The ether produced by the action of sulphuric acid on alcohol and purified with sulphuric acid and potash, however, reacted faintly with potassium iodide and decidedly with hydriodic acid but not with chromic acid; while the ether prepared from methylated spirit and exposed to light contained a considerable amount of hydrogen peroxide. The authors have not been able to ascertain the nature of this impurity in the ether, owing to its minute quantity. The impure ether examined by them which was richest in hydrogen peroxide contained only 0·04 per cent of this substance, although it had been for many years exposed to the light. The authors find, however, that ether absorbs the entire molecule of ozone probably, as turpentine does, and on shaking the ether afterward with

water the latter gave with chromic acid the characteristic blue color due to hydrogen peroxide. Moreover, they have proved further that the slow combustion of ether in presence of water produces hydrogen peroxide. A convenient apparatus for the purpose consists of a large flask, containing enough ether to cover the bottom, mixed with an equal quantity of water, and connected with a wash bottle containing cold water. Through the cork of the flask a wide tube passes, open at both ends, and also a spiral of stout platinum wire and a tube bent at right angles which joins it to the wash bottle. By an aspirator connected with this bottle, air is drawn into the flask by the wide tube. Upon heating the spiral to redness and plunging it into the flask, the current of air may be so regulated as to maintain the spiral at a low red heat. Hydrogen peroxide is continuously formed, the flask being from time to time shaken, the ether forming a peroxidized product which is decomposed by the water producing hydrogen peroxide which is dissolved in this water.—*J. Chem. Soc.*, lvii, 574, June, 1890. G. F. B.

4. *On the action of Carbon monoxide upon Metallic Nickel.*—Mond, Langer and F. Quincke have observed that when carbon monoxide is passed over finely divided metallic nickel between 350° and 450° carbon dioxide is evolved and a black powder containing a varying proportion of carbon and nickel is formed; a small quantity of metal being able to decompose a large quantity of carbon monoxide. A sample containing 85 per cent carbon and 15 per cent nickel, when treated with sulphuric acid, gave up about two-thirds of its metal; the remaining carbon being readily attacked by steam, even at 350°, yielding hydrogen and carbon dioxide only. On allowing the nickel to cool while the carbon monoxide was passing over it, it was noticed that the flame of a Bunsen burner into which the excess of gas was conducted, became highly luminous; and on heating the tube between the metal and the outlet a brilliant mirror of metallic nickel was deposited, mixed with a minute quantity of carbon. Further investigation showed that when finely divided nickel, obtained by reducing the oxide at 400° by hydrogen, is allowed to cool in a slow stream of the monoxide, the gas is very readily absorbed as soon as the temperature has fallen to 100°, and a gas is obtained which the authors call nickel-carbon-oxide, in amount about 30 per cent of the escaping gases. This gas at 180° is decomposed into metallic nickel and carbon monoxide again; four volumes of the monoxide being obtained from one of the new gas. Hence it has the composition $Ni(CO)_4$. The gas is not acted on by alkalies or acids. It reduces ammoniacal solutions of cuprous chloride and silver chloride. Chlorine decomposes it with formation of nickel chloride and carbonyl chloride. When cooled in a freezing mixture, the gas condenses to a colorless highly refractive mobile liquid, boiling at 43°, having a specific gravity of 1·3185 at 17° and solidifying at −25° in needle shaped crystals. Since neither cobalt, iron, copper or platinum forms a similar compound, nickel may be readily purified in this way.

And the authors find that nickel thus purified has an atomic mass of 58·58, agreeing well with that of Russell, 58·74.—*J. Chem. Soc.*, lvii, 749, August, 1890. G. F. B.

5. *Waves in air produced by Projectiles.*—Mach and Wentzel employed photography to study the waves in air produced by the motion of projectiles. In passing through the focus of a photographic lens the projectile caused a discharge from a Leyden jar placed in the axis of the lens, at a distance greater than the point of crossing of the projectile. The illumination produced by the spark served to take an instantaneous photograph of the passage of the projectile. The photograph showed a wave of condensation before the projectile provided that its velocity was more than that of sound. When the velocity was sufficient the wave which preceded the ball had the form of an hyperboloid, of which the summit was in advance of the ball, and the axis of which corresponded to the direction of the ball. There were also traces of conical waves, of which the axes were also in the line of fire and which arose at the base of the ball. Some traces of less distant waves were seen upon denser points of the surface of the ball. All these waves made a less angle with the axis of the projectile than the wave in front. When the velocity was augmented, the angles made by the waves with the line of fire were diminished. When the greatest velocities were attained, the space behind the projectile was filled immediately with little clouds, there was no trace of a vacuum behind the ball even when the velocity was 900 meters per second. The waves produced in the air by the projectile at higher velocities than that of sound progress more rapidly than those due to feeble velocities, so that the compression in front of the projectile is not sufficient to be depicted upon the photograph under the form of waves.—*Revue Scientifique*, Sept. 13, 1890, p. 338.

6. E. Mach and P. Salcher have extended the method of observation employed by Mach and Wentzel to the study of streams of air blown from various orifices.—*Ann. der Physik und Chemie*, xli, p. 144, 1890.

E. Mach and L. Mach have also employed the method for studying the interference of sound waves of great excursion.—*Ann. der Physik*, xli, p. 141, 1890. J. T.

7. *Re-determination of the Ohm.*—Prof. J. V. Jones read a paper on this subject at the late meeting of the British Association at Leeds. He reviewed the method employed by Lorenz and by Lord Rayleigh, and suggested a direct determination of the mercury unit by this method, instead of the employment of solid conductors by the shunt method and afterwards a comparison with a mercury unit. He points out "if the artificial B. A. unit can be dropped out of one's experiments as well as out of the results, and the measurements made directly on mercury, the simplicity would seem to be a recommendation, and the argument is perhaps enforced by the consideration that there is very nearly as much divergence in the results of different observers for the

specific resistance of mercury in B. A. units as there is in the values obtained for the B. A. unit in absolute measure." The author therefore offered the following:—

(1) That the time is ripe for a new determination of the ohm that shall be final for the practical purposes of the electrical engineer.

(2) That such a determination can be made by the method of Lorenz, the specific resistance of mercury being obtained directly in absolute measure by the differential method described.

(3) That the standard coil should consist of a single layer of wire, the coefficient of mutual induction of the coil and disc, circumference being calculated by the new formula. J. T.

8. *Alternating versus continuous currents in relation to the Human body.*—At the meeting of the British Association held at Leeds, 1890, a paper was presented on this subject by H. Newman Lawrence and Arthur Harries. They arrive at the following conclusions:

A. When the human body, with the skin in its normal unmoistened condition, comes into contact for an appreciable time with base-metal conductors of a dynamo-generated continuous current passing at 100 volts in such a way that the current passes from hand to hand, and the total contact area is about 90 square centimeters:

(1) A current of about 0·016 Ampères will pass through it.

(2) This current can be borne without discomfort for 15 to 30 seconds.

(3) After about 30 seconds unpleasant burning sensations become marked and increase.

(4) The subject is perfectly able to release himself at will during any portion of the time of contact.

B. When the human body comes in contact with dynamo-generated alternating currents, alternating at about 60 to 70 per second under the same conditions as above.

(1) A current of about 0·075 Ampères will pass through it.

(2) This current is *six times greater* than that which produces discomfort.

(3) Instantly the subject is fixed by violent muscular contraction and suffers great pain.

(4) The subject is utterly unable to release himself, but remains exposed to the full vigor of all the current that may be passing.

C. When circuit from electric light or power conductors is accidentally completed through the human body, the danger of serious consequences is many times greater when alternating than when continuous currents are passing at equal voltage, and this is still to a large extent true if the voltage of the continuous current be double that of the alternating.

D. (1) With both forms of current a reduction of contact area materially reduces the amount of current strength that passes.

(2) With the alternating current, if the rate of alternation be reduced below 50 per second, the sensations of pain accompanying muscular fixation will be increased, while if the rate of

alternation be increased, the pain will be diminished. The authors state in conclusion that mere statements in regard to voltage unaccompanied by statements in regard to current are highly misleading.—*Electrical Review*, Sept. 12, 1890. J. T.

II. Geology and Natural History.

1. *Phylogeny of the Pelecypoda, the Aviculidæ and their allies;* by Robert Tracy Jackson, S.D., Mem. Boston Soc. Nat. Hist., vol. iv, no. viii, pp. 277–400, pl. xxiii–xxix, 53 figures in the text, July, 1890.—Each time a familiar subject is studied from a new standpoint, many novel and interesting results may be expected. In the present instance, the author has employed modern and approved scientific methods, and the results, while both novel and interesting, are of the highest importance to a proper understanding of the pelecypods. The leading method which is here so fully applied is that of a study of the stages of growth. The embryology and anatomy are constantly kept in view and also the chronological history of each group in past geologic time. If all these aspects of growth can be brought into harmony, we have the strongest evidence of the accuracy of our observations, and most reliable taxonomic data.

Professor Hyatt in his studies of the stages of growth and decline among the cephalopods has constructed a model, and indicated methods which may be profitably applied to all branches of natural history. These principles have been followed by the author, although some particulars have been slightly modified in order to adapt them directly to the pelecypods. A new term is proposed for a stage of growth between the typembryo of Hyatt, which as re-defined is characterized in mollusks by a shell gland with an initial plate-like shell, and the period showing a completed protoconch. This intermediate period the author terms the *phylembryonic*, or that in which the shell and anatomy are each sufficiently differentiated to determine the class to which the organism belongs.

The important discovery of the characters and relations of the larval or embryonic shell named the *prodissoconch* was briefly described in a previous paper by the author, but is here fully treated in its relations and significance in the class. Its existence is demonstrated in about thirty genera belonging to widely differing families of pelecypods, recent and fossil, and is believed to indicate a primitive ancestral condition common to the whole class. The consideration of the oyster and allied forms comprises one of the leading features. The development of the animal and shell is described and illustrated in over thirty pages and three plates. It is shown that the ostreaform shell is due to the cemented condition of fixation, and on this account is closely simulated in other attached shells, in genera and families which are not closely genetically related. In Pecten, the study of the habits and anatomy at different growth-stages shows the intimate

relationships and synchronous variations between the soft and hard parts of the animal. This emphasizes the general truth that the shell is not the mere covering or domicile of the animal, but is a highly specialized enveloping organ, subject to modification from changes in the soft animal within, and to the varying conditions of the environment. From the nuculoid prodissoconch, Pecten passes through stages corresponding to Rhombopteria, Pterinopecten, and Aviculopecten.

A genealogical table for the Aviculidæ and their allies is proposed as a result of these investigations, based upon fossil and recent forms. A nuculoid shell of Lower Silurian type is taken as the radical. The new genus Rhombopteria is proposed for a group of Aviculoids of which *Avicula mira* Barrande is the type. It is considered as the prototype and ancestral form of three distinct branches; one by direct descent through Leptodesma to Avicula, with side branches to Pinna, Perna, Ostrea, Malleus, etc., another doubtful side branch to Pterinea and Ptychopteria, and the third diverging through Pterinopecten and Aviculopecten to Pernopecten, Pecten, Plicatula, Anomia, Placuna, and allied genera. C. E. B.

2. *Revue des travaux de paléontologie végétale, parus en 1888 ou dans le cours des années précédentes;* par le Marquis GASTON DE SAPORTA. Extrait de la Revue générale de Botanique, tome II, Paris, 1890.—This exhaustive review of paleobotanical literature contains much that is original and goes far to settle a large number of the more perplexing problems of the science. The subject is treated by geologic eras, the author's former classification of Paleophytic, Mesophytic, and Neophytic, being employed. As on former occasions he makes the Mesophytic extend so as to include only the Lower Cretaceous, and the Neophytic to begin with the Cenomanian and include the Upper Cretaceous, this being the point in vegetable paleontology where the most distinct line of demarkation occurs. Among the more important points brought out may be mentioned the following: The great difference between the Paleophytic and Mesophytic ferns and those of modern times; the acceptance of the cryptogamic nature of Sigillaria and Calamodendron, so long denied by the French school; the announcement of the discovery of a Lower Cretaceous flora in Portugal containing dicotyledons, and similar to that of the Potomac formation of Virginia; and the surrender of the much discussed problematical organisms called Spirangium or Palæoxyris to the zoologists as of animal nature. L. F. W.

3. *Notes on the Leaves of Liriodendron;* by THEODOR HOLM. Proc. U. S. Nat. Mus., vol. xiii, 1890, pp. 15–35, pl. iv–ix, Washington, 1890.—Mr. Holm is making a study of the germination of plants and of the earlier leaves as they appear following the cotyledons. In this paper he has described and figured a large number of these early leaves of *Liriodendron Tulipifera*, which prove to be very interesting and of special importance to the student of paleobotany, since these early leaves are supposed

to show the stages through which the particular form has passed in its development from earlier times. The genus Liriodendron, as is well known, is a waning type only a single species, or possibly two, remaining in the present flora of the globe, while a large number of fossil species have been described, many of which have leaves which remind us strongly of these embryonic early forms figured by Mr. Holm. As these embryonic forms, however, are not likely to occur in a fossil state, Mr. Holm's contention that there has been an undue multiplication of species by paleobotanists, and that many of the fossil species described are only early forms of living species, is by no means sustained, and he does not seem to understand that these modern embryonic forms are more likely to represent the phylogenetic stages through which the present living species has passed. L. F. W.

4. *Contributions to the Tertiary Fauna of Florida;* by WM. H. DALL. Trans. Wagner Free Institute of Sci., Philadelphia, vol. iii, pt. i, Aug., 1890. 178 pp., 12 plates.—The excellent plan of this series of publications, that of presenting memoirs on the geology and paleontology of Florida, is well exemplified in the present issue. It is aimed to produce a complete monograph of the molluscan fauna of the Caloosahatchie beds, which shall serve as a typical example of an American Tertiary fauna, and as a standard for critical comparisons with other horizons. The present number comprises the greater part of the gastropods, and is to be followed by the second part, to include the remainder of the gastropods, together with the pelecypods and scaphopods. The material employed was collected by Mr. Joseph Willcox, the the author, Mr. Frank Burns of the U. S. G. S., and others.

An important discussion in dynamical evolution, relating to the plications on the columella in the Volutidæ, leads the author to conclude that they are the strongest in those shells having the most deep seated adductor muscles. Also, that the plications are produced by the frequent retraction of the animal, and consequent wrinkling of the large shell-secreting mantle when withdrawn within the shell cone while enclosing the comparatively firm foot and body of the animal. Through an extension of this principle the author also accounts, by similar mechanical reasons, for the teeth and liræ so common and characteristic in many other groups. C. E. B.

5. *On Syringothyris* Winchell, *and its American Species;* by CHARLES SCHUCHERT, from the Ninth Ann. Rept. N. Y. State Geologist. 12 pp. 1890.—The question as to what should constitute the type species of *Spirifer* and *Syringothyris* is discussed by the author, and considerable light thrown on the synonymy of the American species belonging to the latter genus. *Syr. Carteri* Hall is shown to be the same as *Syr. typa* Winchell, and therefore becomes the type. Following Davidson and others *Spirifer striatus* is accepted as the type of Sowerby's genus, although *Syr. cuspidatus* was the first species referred to *Spirifer.* C. E. B.

6. *Mineral Resources of the United States.*—Calendar year 1888, DAVID T. DAY, Chief of Division of Mining Statistics and

Technology. 652 pp. Washington, 1890 (U. S. Geol. Survey, J. W. Powell, Director).—Another volume—the sixth—of this valuable series has appeared, under the able editorship of Mr. David T. Day, and presents the condition of our mining industries for 1888. The volume opens with the usual concise summary for the different metals, etc., and detailed chapters on each subject by individual specialists follow. Some of these chapters are of great fullness and interest as, for example, that in Coal (pp. 168–394) by Charles A. Ashburner. As illustrating the effect of a special demand (in this case, the manufacture of incandescent gas burners) in creating a supply of substances hitherto supposed to be extremely rare, it is interesting to note that during 1887–88, 25 tons of zircon were mined in North Carolina, 4 tons of monazite, 1 ton of allanite, 600 pounds of samarskite and $500 worth of yttrium minerals.

7. *Elements of Crystallography for students of Chemistry, Physics and Mineralogy*, by GEORGE H. WILLIAMS. 250 pp. 12mo. New York, 1890, (Henry Holt & Co.).—The subject of crystallography is often regarded by the student as somewhat repulsive, but to those acquainted with its real simplicity it is obvious that the difficulty is not so much intrinsic as to be found in the way in which it is ordinarily presented. The excellent little volume which Dr. Williams has prepared can hardly fail to do much to remove this reproach and to make the subject thoroughly attractive. The explanations of the morphological relations of crystals are so simple and full and the style so clear that a conscientious student using it will find that the ordinary difficulties disappear while the mastery of the subject will follow as a matter of course. A knowledge of crystals is obviously of importance not only to the mineralogist but also to the chemist and physicist and to the latter class especially this book will be of great assistance.

8. *Rumpfite, a new mineral.*—G. FIRTSCH has given the name Rumpfite, after Prof. J. Rumpf, of Graz, to a mineral allied to the chlorites occurring in aggregates having a fine scaly to granular structure in cavities in magnesite near St. Michael in Upper Syria. It has a greenish-white color; the hardness is 1·5, and the specific gravity 2·675. Before the blowpipe it is infusible. An analysis gave:

SiO_2	Al_2O_3	FeO	MgO	CaO	H_2O
30·75	41·66	1·61	12·09	0·89	13·12=100·12

It was found that practically no water was lost up to 360°, but at a dark red heat 9 per cent went off, while the remainder was expelled at full ignition.—*Ber. Ak. Wien*, xcix, July, 1890.

9. *Polybasite from Colorado.*—Dr. F. M. ENDLICH has identified the rare mineral polybasite at the Yankee Boy mine, Ouray, Colorado. It occurs in tabular crystals, hexagonal in outline, with pyrargyrite in cavities in a quartzose gangue. The determination has been confirmed by Penfield who finds the prismatic angle to be very nearly 60°; Miers gives 60° 10′ as the result of recent observations.

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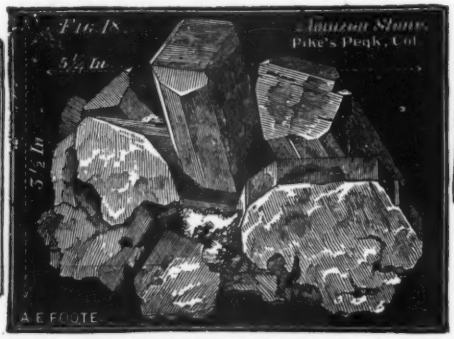

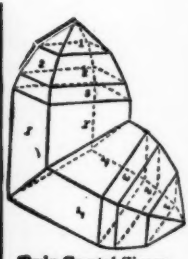

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